Towards Climate Change Adaptation

Building Adaptive Capacity in Managing African Transboundary River Basins

Case studies from African practitioners and researchers







On behalf of:

Federal Ministry
for Economic Cooperation
and Development

inWent

Capacity Building International
Germany

Towards Climate Change Adaptation

Building Adaptive Capacity in Managing African Transboundary River Basins

Case studies from African practitioners and researchers

with International Cooperation Partners

RESEAU AFRICAIN DES ORGANISMES DE BASSIN
AFRICAN NETWORK OF BASIN ORGANIZATIONS
RED AFRICANA DE ORGANISMOS DE CUENCA

inWent
Capacity Building International
Germany

gtz Partner for the Future. Worldwide.

IW LEARN

UNEP

NILE BASIN INITIATIVE
Initiative du Bassin du Nil

Global Water Partnership
Eastern Africa

Imprint

Towards Climate Change Adaptation - Building Adaptive Capacity in Managing African Transboundary River Basins.
Case studies from African practitioners and researchers

Edited by
Thomas Petermann, InWEnt

Published by
InWEnt - Internationale Weiterbildung und Entwicklung gGmbH
Capacity Building International, Germany
River Basin Dialogue Programme (ASTRA No. 1008700000)
Division 5.02: Natural Resources and Biodiversity
Lindenstraße 41 (Zschortau). 04519 Rackwitz, Germany

Disclaimers
The content and views expressed in this publication are the responsibility of the authors and do not necessarily reflect the views or policies of InWEnt. The designations of geographical entities in this report, and the presentation of material, do not imply the expression of any opinion whatsoever on the part of InWEnt concerning the legal status of any country, territory, or area, or of its authorities, or concerning the delineation of its frontiers or boundaries.

Citation: Petermann, T. (Editor) 2008. Towards Climate Change Adaptation - Building Adaptive Capacity in Managing African Transboundary River Basins. InWEnt, Zschortau, Germany

Cover Photography
InWEnt (11); Gilberto Vicente (1)

Layout
Nicole Fritsch, Leipzig

Germany
December 2008

ISBN: 978-3-939394-28-0

Contents

Foreword

It has become widely recognised that climate change will have one of its most telling impacts on Africa's water resources. This emerging threat poses an additional challenge to a continent already grappling with a highly variable hydrological regime. Water management institutions and river basin organisations in particular are called upon to urgently develop adaptation strategies to minimise disruption of economic and social development on the continent. At the core of adaptation, change and development, we find a learning process of all stakeholders involved. Successful implementation has been shown to benefit from strong political will and shared expert advice within the framework of an enabling learning environment that allows these two to grow and yield results.

There is already a skilled body of expertise in Africa working towards improving the ability of African countries to sustainably manage their transboundary water resources. In this publication, 14 practitioners and researchers from Africa provide an in-depth insight into technical, social and economic dimensions that affect people as well as the governance and management of land and water resources in a river basin context. At the same time it provides solutions and "hands-on" experiences of how to adapt to these challenges at national and transboundary decision making levels and so meet the future water demands of a rapidly growing population and developing economic situation.

Blending the elements of an enabling environment together in time and place is the core mandate of InWEnt, the German Capacity Building Organization commissioned by the German Ministry of Economic Cooperation and Development (BMZ). The multiple challenges that Africa is facing in managing its water resources in light of global climate change and its efforts to succeed are a priority of German development policy.

This publication is an output of the InWEnt program "**River Basin Dialogue Programme (RBD)**" that aims to build capacity amongst African River Basin Organisations and so, allow them to be-come stronger and to successfully comply with their mission and goal in face of the challenges mentioned above. One component of RDB is to strengthen African institutions in their efforts to adapt to the impacts of climate change. It supports the **African Network of Basins Organisations (ANBO)** and its member organisations, policy makers, national agencies and regional development organisations (for example SADC), as well as NGOs and research institutions in assessing climate-related vulnerabilities, sharing their knowledge and technologies generated within Africa and developing effective adaptation options. This is in part fulfilment of a core mandate of ANBO, which is to promote and coordinate exchange of knowledge, expertise and experience in the area of transboundary water resources management.

We hope this publication will be a relevant and practical contribution to the body of practice for today's African river basin managers and other professionals involved in integrated water resources management. It shows evidence of both practice-oriented and science-based work in Africa's water sector on climate change issues. May the sound advice and practical recommendations it contains be put into practice and assist the political leaders and decision makers who see wisdom in supporting these efforts.

Reginald TEKATEKA, ANBO Chair and Chair GWP-Southern Africa, Pretoria
Barbara KRAUSE, Acting Head of Department Environment, Natural Resources and Food, InWEnt - Capacity Building International, Germany

Impacts de la Variabilité Climatique et du Changement Climatique dans les bassins fluviaux et lacustres africains – et Mesures d'adaptation: deux questions centrales pour le Réseau Africain des Organismes de Bassin (RAOB/ANBO).

Les changements climatiques sont actuellement considérés comme l'une des menaces les plus graves posées au développement, avec des impacts significatifs sur l'économie des pays en développement et les moyens de vie des populations les plus pauvres de la planète. En général, la variabilité climatique se réfère à la variation naturelle intra et interannuelle du climat, alors que les changements climatiques désignent un changement du climat attribué directement ou indirectement aux activités humaines qui altèrent la composition de l'atmosphère globale et qui s'ajoutent à la variabilité climatique naturelle observée sur des périodes de temps comparables (UNFCCC, 1992).

Compte tenu de la difficulté de dissocier variabilités et changements climatiques, en particulier dans le contexte africain, et pour éviter des débats d'écoles inutiles puisqu'à notre avis les enjeux sont ailleurs, nous proposons d'utiliser la notion de « variabilité et changement climatique ». Ainsi, la notion de variabilités et changements climatiques désigne la modification ou variation significative du climat, qu'elle soit naturelle ou due aux facteurs d'origine anthropique (Niasse M., Afouda A. et Amani A., 2004). Une telle définition a pour avantage de simplifier celle donnée par la Convention Climat et aussi de prendre en compte celle du GIEC qui considère le changement climatique comme une variation à long terme du climat, qu'elle soit d'origine anthropique ou naturelle.

De manière générale, la variabilité et le changement climatique s'est manifesté en Afrique par la baisse chronique de la pluviométrie avec comme entre autres conséquences, une baisse importante de l'hydraulicité des cours d'eau dans l'ensemble des bassins fluviaux et lacustres.

La baisse des débits des cours d'eau et le rétrécissement des superficies des lacs ont entraîné des pertes importantes de terres cultivables, d'espèces animales et végétales et plus globalement la baisse voire la disparition par endroits d'activités socioéconomiques qui étaient les bases de productions des populations riveraines. Face à ces multiples problèmes et pour trouver les réponses adéquates, certains Etats riverains ont dès l'aube des indépendances (1960), décidé de conjuguer leurs efforts pour créer le cadre institutionnel et juridique d'une gestion concertée des -eaux transfrontières, notamment par la mise en place d'organismes de bassin.

Aussi pour approfondir et démultiplier les cas de succès notés dans certaines expériences à travers l'Afrique mais également dans d'autres continents, un Réseau Africain des Organismes de bassin (RAOB) a été créé à Dakar en 2002 avec l'appui du Réseau International des Organismes de Bassin (RIOB).

Le RAOB étant un espace de concertation et d'échanges d'expériences, une de ces mission principale aujourd'hui est d'impulser et de faciliter la coordination de toutes les initiatives d'où qu'elles viennent, ayant comme objectifs d'aider l'Afrique à se doter des capacités humaines et techniques pour d'une part ; pouvoir identifier et mesurer les impacts liés à la variabilité et au changement climatique dans les bassins fluviaux et lacustres et d'autres part, pouvoir trouver les réponses idoines en terme d'adaptation audits changements. C'est d'ailleurs dans ce sens que se situe la coopération entre InWEnt, la GTZ et le RAOB et nous profitons de l'occasion pour remercier au nom de l'Afrique la coopération allemande et tous les autres partenaires qui l'accompagne dans cet appui qu'elle apporte à notre Réseau.

Tamsir NDIAYE, Secrétaire Exécutif du RAOB/ANBO. OMVS, Dakar, Sénégal

Executive Summary

14 illustrative case studies from African practitioners and researchers reflect the state of knowledge as regards climate change scenarios, impacts and vulnerability assessments in African river basins. They provide a detailed insight into the multiple challenges and solutions associated with managing transboundary water resources in Africa. The social and economic dimensions of climate change adaptation are assessed in light of the technical and management-related responses of key sectors and vulnerability aspects, as well as the institutional dimensions in terms of the capacity to react to the manifold impacts of global climate change.

The studies were presented at the regional seminar "**Building adaptive capacity – Mainstream adaptation strategies to climate change in managing African transboundary river basin**" held in Entebbe, Uganda from 26-29th August 2008 under the auspices of the African Network of Basin Organisation (ANBO) and in the policy framework of the African Ministerial Council of Water (AMCOW).

Hosted by the Government of the Republic of Uganda, the seminar was jointly organised by a group of International Cooperation Partners: GTZ, InWEnt, GEF IW:LEARN and African Water Governance, UNEP, GWP East Africa and the Nile Basin Initiative based at Entebbe.

It convened around 60 executives, senior programme coordinators and project managers from African transboundary River Basin Organisations (RBO), Lake Authorities and their national organisations, as well as delegates from government, UN organisations and GEF/UNDP supported projects, regional development organisations, researchers and NGOs.

The goal was to take stock of the present knowledge on climate change in Africa, to discuss activities and research findings, and to develop realistic adaptation strategies to manage transboundary river basins under the conditions of climate change (see table next page).

The "**Entebbe Declaration**" (page 19) expressed the key message of delegates and provides a sound basis for future regional networking and outreaching to "act on climate change to advance sustainable development in African river basins". The Entebbe seminar findings are summarized in the **Policy Brief: Towards a Policy and Climate Change Adaptation for Shared Lake and River Basins in Africa** (page 21).

While the seminar in Entebbe placed emphasis on sharing data and information, learning from experiences and developing a broad concept to mainstream climate change adaptation in river basin organisations, future follow-up initiatives will focus more on operational issues. They aim to strengthen the capacity of shared watercourse institutions at all levels to react to climate change and variability in managing transboundary river basins sustainably. Regional dialogues will be jointly conducted with GEF/UNDP and sub-regional partners in West Africa (Abuja, December 2008), followed by Southern and East Africa in 2009. The focus will be on strengthening institutional arrangements as well as mechanisms related to technical, structural and organisational measures to cope with climate change impacts in river basins.

Climate change scenarios and impacts Keynote speakers from WMO and IPCC/IDRC	Keywords: Climate change scenarios; scenarios on impacts, vulnerability assessments and adaptation	Chapter: 1 Datius Rutashobya (WMO) Chapter 14: Anthony Nyong (IPCC/IDRC/AfDB)
Adaptation to Climate Change: The multiple challenges and solutions in manging water resources	Keywords: Case studies on integrated water resources management; responding to climate induced risks; floods and droughts; ecosystem management; water infrastructure management in a changing environment, transboundary groundwater management	Chapter 2: Roland E. Schulze Chapter 3: Madiodio Niasse Chapter 4: Boaventura Cuamba / Genito Amós Maúre Chapter 5: Hillary Masundire Chapter 6: Enoch Dlamini Chapter 7: Michael James Tumbare Chapter 13: Ousmane Diallo
Socio-economic dimensions of Climate Change Adaptation: Responses in key vulnerable sectors	Keywords: Case studies on agriculture; food supply; irrigation and adaptation mechanism; implications for rural livelihoods	Chapter 8: Amos Majule Chapter 9: Peter Johnston et al. Chapter 10: Gina Ziervogel
Institutional dimensions: The capacity to react	Keywords: Mitigation and adaptation mechanism; policy, planning and operational levels; regulations; role of civil society and NGOs	Chapter 11: Audace Ndayizeye Chapter 12: Oweyegha Afunaduula
Policy Statements	- The Entebbe Declaration, August 2008 (page 19) - Policy Brief: Towards a Policy and Climate Change Adaptation for Shared Lake and River Basins in Africa : Executive Summary of the Entebbe Seminar 2008 (page 21) - The Kampala Statement. Groundwater and Climate in Africa: Kampala Conference 2008 (Annex 1) - The 6th Petersberg Round Table on Transboundary Water Management in Africa: BMZ 2007 (Annex 2)	

Acknowledgements

This publication is produced in the context of the Seminar "**Building adaptive capacity – Mainstream adaptation strategies to climate change in managing African transboundary river basin**". InWEnt is grateful to the authors for providing their case studies and research papers to help with assessing climate-related vulnerabilities and to evaluate and develop adaptation options, based on latest scientific research and hands-on experiences in Africa.

This publication of papers is produced in conjunction with the seminar documentation as well a CD-sampler of all presentations held at the seminar and further background material on climate change with regard to the impacts on managing water resources. Most documents will be accessible as pdf-files on the InWEnt Alumni website Global Campus 21:

www.gc21.inwent.org/nrm-net
Go to <Themes> then <Climate change adaptation>
or
Go to <Programme Overview> then <River Basin Dialogue>

The 14 African experts dealing with climate change issues were jointly selected by InWEnt, Thomas Chiramba of UNEP Nairobi and Simon Thuo of Global Water Partnership, GWP-East Africa. Our thanks also goes to Paul Block of the International Research Institute for Climate and Society, Columbia University NYC and research affiliate with GWP-EA, Entebbe who made valuable comments on the first drafts of the papers. Alasdair Thompson undertook the language editing.

Introduction

Get Ready: Adaptation to Climate Change Impacts in the Water Sector and Transboundary Water Cooperation

By Thomas Petermann, InWEnt Germany

Get Ready. Changes in water availability are what hit Africa first with an altered climate. Beyond the stronger, less predictable and more frequent natural disasters resulting from climate change, regions across the world are already suffering from the effect climate has on the water balance: „Too much water or too little water; water at the wrong time or the wrong place; rising sea levels; and floods in certain regions while droughts in others" (SIWI World Water Week Focus 2007, p.6). These impacts on water cycles will cause adverse effects on hydro-energy supply, food security and public health and will, therefore, progressively impact on the life of all humans: **Water is a multi-sectoral resource that links to all facets of life and livelihood, including security.**

No one can say today they are adequately prepared for these changes. Disaster management mechanisms and strategies in Africa are still only poorly developed and implemented. Consequently, adapting to climate change has become an issue of major concern, especially the question as to what Africa must do in order to adopt suitable adaptive measures to cope with water scarcity, climate variability, rainfall uncertainty and increasing vulnerability due to global climatic change. Isolated solutions are not an option because most water resources in Africa are shared between two or more countries; thus demanding integrated and transboundary water resources management (see fig 0.1 and map 0.1).

The effects of global warming are summarized in the reports of the Intergovernmental Panel on Climate Change (Climate Change, IPCC 2007; Climate Change and Water, IPCC 2008). Climate models show a consistant response in both annual and seasonal temperature change in all African sub-regions and individual models generate large responses towards either wetter or drier conditions in different sub-regions. Global models still have limitations in and around Africa due to insufficient information and significant systematic errors because they do not fully consider the impacts of future land surface changes or, for example vegetation cover feed-back, and the impacts of ocean currents. Nevertheless,

Box 1: Africa – Atlas of Our Changing Environment. UNEP 2008

"The Atlas clearly demonstrates the vulnerability of people in the region to forces often outside their control, including the shrinking of glaciers in Uganda and Tanzania and impacts on water supplies linked with climate change." Achim Steiner, UNEP Executive Secretary.

Environmental changes and challenges over the past 35-years are associated with land conversions, land degradation and desertification, deforestation, loss in biodiversity, water scarcity or shortages, water pollution, shrinking glaciers, drying up of lakes, and so on.

Climate change is emerging as a driving force behind many of these problems and is likely to intensify the already dramatic transformations taking place across the continent.

Over 300 million people in Africa already face water scarcity or water shortages. Continued climate change will aggravate this situation. By 2050, it is expected that areas experiencing water shortages in sub-Saharan Africa will have increased by 29%. By 2100, water flow in the Nile River region is expected to decrease by 75%, with damaging consequences for irrigation practices.

Although Africa produces only 4% of the worlds total carbon dioxide emissions, its inhabitants are poised to suffer disproportionately from the consequences of global climate change.

Africa's capacity to adapt to climate change is relatively low, with projected costs estimated to reach at least 5-10% of GDP.

Finally, transboundary issues are a key feature of Africa's environment, from international river basins to cross-border air pollution.

Source: UNEP 2008
www.unep.org/dewa/Africa/AfricaAtlas/

the generalized climate change trends are:

All of Africa is very likely to warm during this century. The warming is very likely to be larger than the global, annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moister tropics.

Annual rainfall is likely to decrease in much of Mediterranean Africa and northern Sahara, with the likelihood of a decrease in rainfall increasing as the Mediterranean coast is approached. Rainfall in southern Africa is likely to decrease in much of the winter rainfall region and on the western margins. There is likely to be an increase in annual mean rainfall in East Africa. It is uncertain how rainfall in the Sahel, the Guinean Coast and the southern Sahara will evolve in this century

(Source: IPCC 2007. Climate Change. Fourth Assessment Report. Working Group I Report: The Physical Science Basis. Chapter 11.1. p.866).

In Africa the effects are already visible in, for example, the drying up of Lake Chad, the disappearance of glaciers atop Mount Kilimanjaro, extreme weather variations throughout East and Southern Africa. The UNEP "Africa – Atlas of our changing environment" highlights striking examples of climate variability and change in Africa's ecosystems (Box 1).

Scientist have long predicted that global warming will inevitably interfere with rainfall patterns and lead to extreme whether events such as the frequency and severity of drought, flooding, heat waves and storms, because air and sea temperature and sea-level atmospheric pressure, the underlying forces behind these pattern, are already changing. And increasingly evidence exists, beyond the anecdotal or in computer models, that fundamental "superimposed" changes are already occurring much faster than through traditional "natural" cycles of climate change or dynamic.

Although the Africa continent has contributed least to the global warming problem – associated to human activity such as carbon dioxide emitted from fossil fuel consumption – Africa will be seriously hit by changing climate patterns and many ecosystems are likely to be overburdened by an unprecedented combination of climate change and its associated disturbances such as floods, drought, wildfire and other natural calamities (IPCC 2007).

Action on reducing the build-up of greenhouse gases is not the topic of this publication, climate change can be tackled everywhere in the world. In Africa, measures can also be taken to mitigate and prevent greenhouse gas emissions. Many components of Africa's climate are perfectly suited for the exploitation of alternative energy; especially from wind, sun and ocean waves, but also other renewable energy technologies including bio-fuel, biogas, hydrogen and hydropower offer opportunities.

Box 2: Likely impacts of climate change on coastal and marine ecosystems

In Tanzania, for example there will be a loss of land; coastal erosion and damage to coastal structures and properties; loss of coastal and marine ecosystems, for example mangroves, fish, coral, and sea grass beds; saline intrusion in fresh water bodies and aquifers; inundation of low-lying coastal areas and small islands; reduced freshwater flows and changes in pulsing of flows to estuaries, and the reduction in the annual flow of many rivers.

Source: J. Tobey and S. Mwakifwamba, Climate Change Vulnerability and Adaptation. IMCAFS Vol. 2, Issue 1, Jan 2008

Seas of Change

Studies in South Africa show oceans heating up and associated signs of severe stress on ecosystems. Shifts of temperatures, ocean currents and wind conditions are some of the expected effects of global warming. The map of southern Africa shows how ocean temperatures have changed over the past two decades. There is sufficient evidence that the change in the oceans is linked to global warming. This causes unusual weather conditions and a shortage of fish especially in the Benguela current large marine ecosystem off the coasts of Angola, Namibia and South Africa. Amongst the most significant changes are: Increase in warm events; a general warming south of Cape Agulhas; long-term increase in the strength of southerly winds; a ten-fold increase in zoo plankton, caused partly by changes in wind patterns; decline in rock lobster population, due partly to an increase in low-oxygen water.

Source: Michael O'Toole UNDP, Chief Technical Advisor, Benguela Current LME. Adapted from an GEF IW:LEARN-InWEnt-UNEP seminar presentation in 2007, Nairobi.

The challenges ahead. African scientists have already proven and illustrated the complex nature of the likely impacts that global climate change have on coastal and marine areas (Box 2). These impacts will directly affect the livelihood of millions of people, urban and rural water supply, hydropower, irrigation, and so on.

Increasing populations, changes in economic activities and lifestyles in urban areas and changes in land uses for agricultural production will result in changing pattern of water uses. This will further pressurize Africa's freshwater resources and exacerbate problems related to timing and quality of water supplies. The high spatial and temporal variability of water resources availability and its uneven distribution means that water scarcity is already a major current concern in many parts of Africa. Climate change threatens to put further pressure on water resources already under pressure (see figure 0.1 and box 3). Studies also show greater proportional changes in river flows than precipitation and responses to increasing temperature or evaporation. This may put further pressure on groundwater resources to meet future water demands.

The current knowledge of the potential impacts of climate change on water resources in Africa are summarized in IPCC 2008 (Bates et al. 2008. Climate Change and Water. Technical Paper. IPCC Secretariat, Geneva) and Goulden et al. 2008 (Tyndall Centre for Climate Change Research, WP 127, UK).

It is clear that current water management practices are likely to be inadequate to reverse the impacts of climate change. Flexible water management that accommodates new understandings of water balance scenarios are imperative for societies to be able to adapt. In practise, this involves, for example, risk assessments and cost-benefit analysis of managing water resources that both protect the vulnerable in society against hazards and take advantage of new opportunities to increase water efficiency and equity.

Fortunately, people are not helpless and the capacity to adapt can be strengthened by drawing attention to the determinants of adaptive capacity such as different types of social capital, institutions and governance arrangements. The IPCC defines adaptation as "how individuals, groups and natural systems can prepare for and respond to changes in climate to avoid or reduce impacts." Hence, adaptation requires making systems more resilient and healthy not just for today but for the long-term, for example by reducing human-made pressures or restoring ecosystems, by investing in projects that reduce vulnerability of infrastructures and people, or through capacity building for „just better planning" towards integrated water resources management or in public awareness and education campaigns geared towards more environmentally friendly choices and options. In this respect, decisions on adaptations must be made at a diverse range of levels and consider a variety of time scales and geographies.

Box 3: Key Issues in climate change – empowerment and institutional arrangements

Understanding climate change is based in physical science; however, responding to climate change is based on economic empowerment and strengthening institutional arrangements. Adaptation based responses to climate change raise development issues rather than scientific or technical issues. Climate science is nonetheless a necessary part of the process of analysing the impacts of climate change, for example as a basis for developing scenarios on the consequences of climate impacts. An appropriate regional response, therefore, needs to be well integrated with the region's key development issues and poverty alleviation efforts. Furthermore, the complexities and risks of climate change should accelerate the need for implementation of social and economic empowerment initiatives. This reinforces the need for a risk based approach to dealing with the potential impacts of climate change, where 'best estimates' based on climate science underpin analysis and the prioritisation of responses. Waiting for precise climate projections to emerge from the various climate models under development will decelerate the response process.

Society, judiciary and governments are typically not structured to deal with the cross-sectoral nature of climate change and coordination is needed to stimulate inter-sector responses. It is evident from the above that the current state of affairs in southern Africa will prevent it from minimizing the effects of the identified barriers to respond to climate change without support. Although some development strategies demonstrate a level of integration, many fall short in implementation, precisely because of the way governance functions.

Source: Regional Climate Change Programme (RCCP) for Southern Africa. Funded by DFID and prepared by OneWorld Sustainable Investments. DFID Feasibility Executive Summary. Draft January 2008

- **Water Governance.** In Africa the challenges ahead in the water sector are manifold. However, they cannot only be attributed to a rapidly growing demand due to population growth, regional scarcity in water availability, industrial pollution and socio-economic development. Water governance mechanisms are often weak and institutional constraints hamper the implementation of an "integrated water resources management, IWRM" regime towards the sustainable and equitable use of water resources. In addition, most water resources (rivers, lakes and groundwater) in Africa are shared between one or more neighbouring countries with different policies, governance regimes and socio-economic development standards. They also differ in their human, technical and financial capacities to react. Hence, coordination mechanism must be in place to govern the use of water resources across borders.

- **Dialogue.** An important step forward would be the identification of realistic adaptation strategies for transboundary river basin organisations that follow the recommendations of the **„African Ministerial Roundtable on Climate change - Towards a stronger response to threats of adverse climate effects"** held on 16-17th Nov 2007 in Jinja, Uganda ahead of the Commonwealth

Heads of Government Meeting 2007. The „**Jinja Declaration on Climate Change**“ highlights the role of capacity building at all levels and the need to enhance adaptation measures into concrete adaptation activities at national and local level.

The **6th Petersburg Round Table on Transboundary Water Management in Africa** – “From agreements to investments - how to put measurable value to transboundary water cooperation in Africa”, convened in September 2007 by the German Federal Government, AMCOW, the WB, GEF and UNDP emphasised that transboundary water management is a key issue in the adaptation to climate change and will be of crucial importance for political and socio-economic stability and economic growth. Expected changes in the hydrological cycle and impacts on agriculture and food security need to be assessed, and water management plans and infrastructure development should consider future changes in water availability. Additionally, political dialogue across borders needs to be strengthened and information systems developed while institutions at all levels must develop such capacities to cope with climate change. (Annex 1).

GTZ and InWEnt – on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) – are taking up this challenge and in conjunction with international cooperation partners GEF IW:LEARN, GEF/UNDP, UNEP and GWP will organise a series of regional dialogues under the auspices of ANBO and the policy framework of AMCOW and regional development communities, for example SADC and EAC. The focus of the dialogues is to strengthen the capacity to manage transboundary river basins in Africa through “mainstreaming strategies on adaptation to climate change in the development and implementation of river basin plans and programs“.

The “**Kampala Statement – Groundwater and Climate in Africa**” signed by participants of the “Groundwater and Climate Conference” from 24-28 June 2008 in Uganda provided a better understanding of the potential impacts of climate change on groundwater resources and the development that depends on these resources (Annex 2; for details: www.gwclim.org). Therefore, the Entebbe seminar focused on River Basin Organisations, with due consideration of the importance of managing transboundary aquifers.

Linking Adaptation and Development. The common challenge that all countries face is to mainstream adaptation measures into development planning and decision-making, while considering climate change scenarios and vulnerability. Mainstreaming can be defined as “...using or creating mechanisms that allow decision-makers to integrate future climate risks into all relevant ongoing policy interventions, planning and management” (Luers and Moser. California Climate Change Centre, 2005). While the value of mainstreaming climate change considerations into planning is widely recognized, there are few examples of such action being taken. Thus, there is little experience on ‘how to’ mainstream adaptation measures and strategies into development decisions and planning. The Entebbe seminar, therefore, tries to look for tangible answers for *Linking Adaptation to Development* and to identify realistic adaptation strategies for transboundary river basin organisations.

Capacity building. Strengthening and up-scaling institutional capacity development will be essential in helping African shared watercourse institutions to cope with the future challenges presented by climate change and variability. The role of capacity building in terms of improved awareness, knowledge and skills of individuals will be critical as only informed, skilful managers and planners can make the right decisions at the right time. Regional dialogue and networking are additional components in an comprehensive capacity building approach.

The GEF programme IW:LEARN: International Waters - Learning and Exchange Resources Network (www.iwlearn.org) promotes all these instruments through sharing concepts and practical experiences amongst decision makers, managers and professionals from transboundary river basin organisations (including lakes, groundwater aquifers), national agencies, international cooperation partners, academia and environmental and social development focused NGOs.

Since 2006 InWEnt has been a partner of GEF IW:LEARN in Africa, facilitating structured learning and information sharing amongst stakeholders. Issues of climate change adaptation will play an increasingly important role in future, involving scientists, engineers, development workers and planners as well as experts from related fields in order to create an opportunity for discussion and sharing observations and information on research, best practice and lessons learnt in Africa.

We have to learn interpretation, to apply better planning, implementation and enforcement mechanism – not reinventing the wheel in panic.

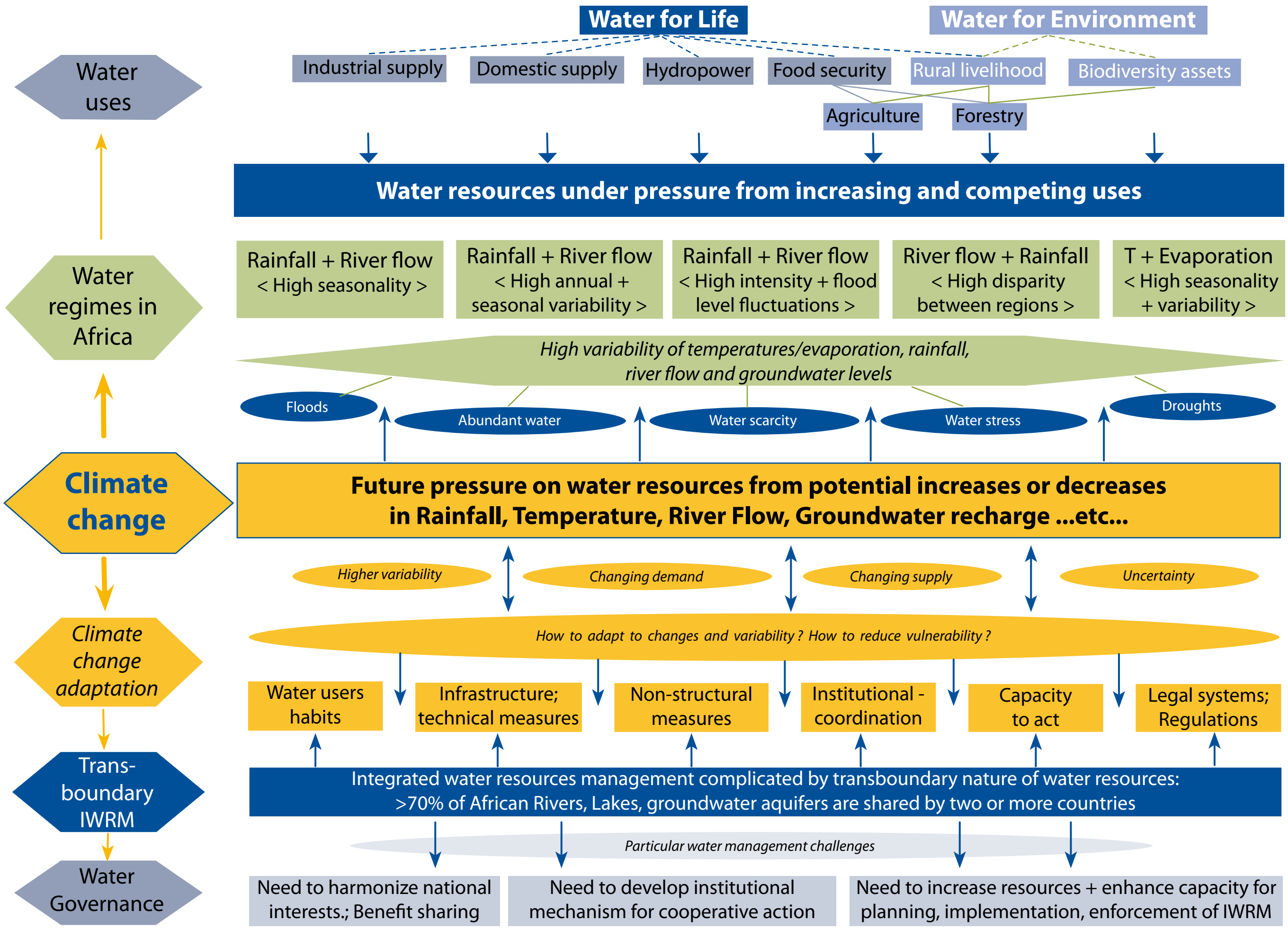


Figure 0.1: Linkages between climate change, water resources, livelihoods, and transboundary water management in Africa

The German Experience in Water Resources Management

The necessary South-South dialogue and networking should be accomplished by learning from approaches and experiences on vulnerability assessments and CC adaptation strategies that already exist in Europe or elsewhere.

For example, the German water sector has developed some basic principles of adaptation to climate change to address the new challenges with actions at policy, institutional, technical and non-structural levels. These will be embedded in a national adaptation strategy that is under development by the German Federal Government (2008). In general, the IPCC models and recent sub-regional models predict drier summers, wetter and milder winters and more intensive rainfall for Germany. In the Rhine River catchment for example, higher flood levels are expected in winter and lower levels during the summer season with potential impacts on all users along the whole river system (Wasserwirtschaft KW 12/2006: 29-31, DWA).

Preventive measures need to be addressed in an integrated, i.e. multi-disciplinary and cross-sectoral approach. Apart from **no-regret measures** (see list of flood risk mangement, page 15), greater **flexibility in policy and administration** is therefore required to prepare for and adapt to climate change.

There are two main elements involved in managing most of these changes relevant for water resources management: Risk reduction and coping with higher variability. These can be illustrated using the example of flood management in Germany (DWA KW 1/2008; DKKV Publ. 29e, 2004). The traditional safety mentality or the (politically desirable) promise of total protection must be converted into a risk culture; that is, a society which is aware of the threat posed by natural disasters such as floods and which accepts dangers and risks, as well as living with changes and deals collectively with uncertainties. Risk culture is based on the following questions:

- What can happen? Tool = Risk analysis, based on competent assessment of danger potentials (probability, magnitude)
- What should not be allowed to happen? What safety stan-

dards must be observed? What safety for what price? Tool = Risk evaluation

- What is the best way (technical and management options that are economically viable and socially acceptable) of dealing with the risk? Tool = Risk management.

Proposals for immediate actions in the German water sector, based on group Delphi approaches, conferences and experts views are summarized on pages 15-16. (Sources: DWA Symposium Klimawandel - Was kann die Wasserwirtschaft tun? H.B.Kleeberg (Edit.) 2008; www.dwa.de; www.WASKLIM.de).

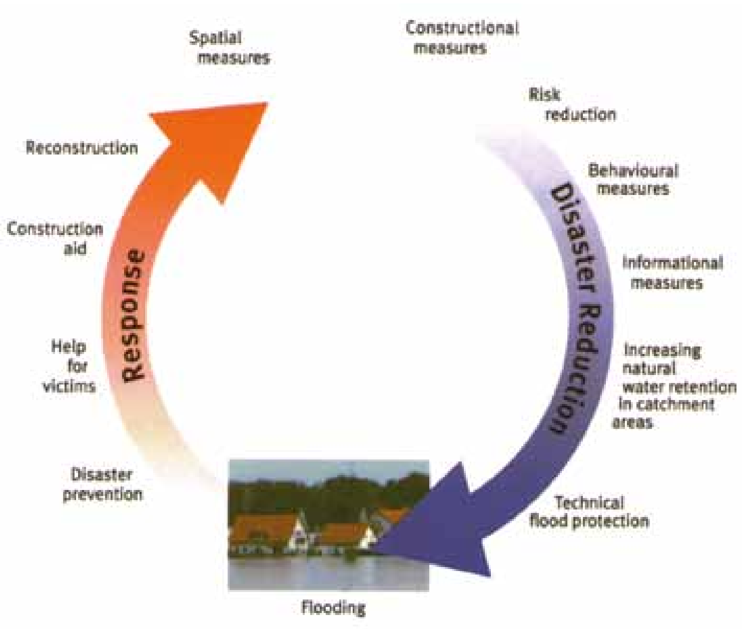


Figure 0.2: The Cycle of Flood Risk Management in Germany. DWA, KW 1/2008

Major elements of flood risk management

1. Preventive measures in the catchment
   - risk management maps
   - adjusting regional planning and urban land use planning; adapted construction of infrastructure, buildings
   - increasing or restoring retention capacity in the whole catchment; adjustments in agriculture, forestry and infrastructure required
2. Technical flood control measures, e.g. dikes, polders, retention basins, emergency facilities
3. Complementary flood prevention measures, e.g. information and early warning systems; individual risk management/insurance; institutional cooperation: cross-sector and across administrative borders

after: Grünewald (DWA Korrespondenz Wasserwirtschaft KW 2004 und 2008). Website: www.dwa.de/KW

Climate change adaptation – A summary of practical implications and experiences in Germany

Climate Change has implications for

- Flood management in river basins
- Low flow conditions in rivers
- Water protection systems (for multiple uses)
- Groundwater regimes
- Water supply (for domestic uses)
- Water supply (for agricultural uses)
- Water supply (for industrial uses)
- Water supply for power plants (cooling systems)
- Hydropower generation
- Navigation
- Recreation (water-based)
- Land use and land productivity
- Others

Action required in the following sectors

- Low flow management (in rivers)
- Land use planning in floodplains (for flood protection)
- Reservoir management (to manage water releases)
- Groundwater management
- New or enlarged water protection zones
- Water production (supply schemes)
- Irrigated agriculture
- Power production
- Navigation (related to low flow and floods)
- Agriculture (in water protection zones)
- Forestry and watershed management
- Water saving (in general)
- Water supply (all users)
- Land use planning for water protection zoning and e.g. groundwater augmentation
- Others

Action is required at the following levels

- Public water supply services
- National level
- State level (German Länder; Provinces)
- Local government (districts, communities)
- Business sector (companies, farmers etc.)
- Individual household level
- Others

Types of actions

- Information systems
- Public awareness campaigns
- Science and research
- Structural measures (in the water sector and other sectors using water or being impacted by water)
- Non-structural measures (in the water sector and other sectors using water or being impacted by water)
- Others outside the water sector

Important structural measures

- New design criteria in water supply
- New design criteria in wastewater management
- New design criteria in flood protection

Hotly debated issues with likely low public consensus

- Water reservoir management (increasing capacity; adapting management, especially base flow regimes)
- Water transfer schemes (for domestic or industrial supplies)
- Navigation (base flow regimes)
- Increased irrigation demand
- Others

Types of CCA measures – based on timing, goal, motive or process of implementation

- Reactive and anticipatory
- Autonomous and planned
- Private and public
- Behavioural, technical, institutional, financial, regulatory

Forms of CCA – in terms of robustness, flexibility and changing vulnerability

- Increasing robustness of infrastructural designs and long-term investments
- Increasing flexibility of vulnerable managed systems
- Enhancing adaptability of vulnerable natural systems
- Reversing trends that increase vulnerability
- Improving societal awareness and preparedness
- Imposing user restrictions

Changing floodwater management will be of paramount importance in Germany. Long-term actions

- Restoration of wetlands
- Rebuilding connectivity

Web-based information service for authorities and the public sector

- Water levels
- Discharges
- Groundwater levels
- Water temperature, oxygen with critical levels
- Implications for water storage in reservoirs and water releases
- Recommendations to the public and water suppliers, industrial users, for example user restrictions

Challenges (summary): What we need to do in Germany?

- Preparedness for changes in water supply and demand management
- Increase in water consumption in some sectors, e.g. irrigation demand; summer season drinking water supply
- Increase seasonal storage capacity (reservoirs)
- Dealing with insecurity (in weather predictions)
- Models and WM-planning for different landscape systems (regions)
- Stakeholders must cooperate and be coordinated beyond administrative boundaries; the planning unit must be a river basin
- New administrative structures, procedures and regulations need to be developed
- CCA requires mainstreaming across-sector policies
- CCA requires new instruments for benefit sharing and risk management

"It is not important to predict the future exactly, but to be prepared for the future"
Pericles, Statesman. Athens. 500 BC

"Nature has no disasters – only humans know disasters. If they survive"
Max Frisch. German poet

Policy framework for climate change adaptation

Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies.
The capacity to adapt is dynamic and influenced by economic and natural resources, social networks, entitlements, institutions and governance, human resources, and technology.
(IPCC 2007. Technical Paper. Working Group 2)

Just as important as technical and water-management related adaptation measures are those that need to be undertaken at institutional level. These include new ways to organise cooperation and data information and decision-making systems at both national and international levels. Further, sector-wide approaches in managing water resources for multiple uses need to be enhanced, and - equally important - cross-sector cooperation and information systems need to be established to include other sectors (e.g. energy, agriculture, health) and users in urban or rural areas who depend on water as a resource of life and income.

The following tables provide an overview on the policy framework on climate change adaptation, the guiding principles of climate change adaptation and how to cope with climate change. *(Modified after Richard Klein, PIK Potsdam: Adaptation, Adaptive Capacity and Stakeholders. Presentation at a Workshop: Climate Change Impacts and Adaptation for Coastal Zones, Abu Dhabi 2004)*

Adaptation and Mainstreaming

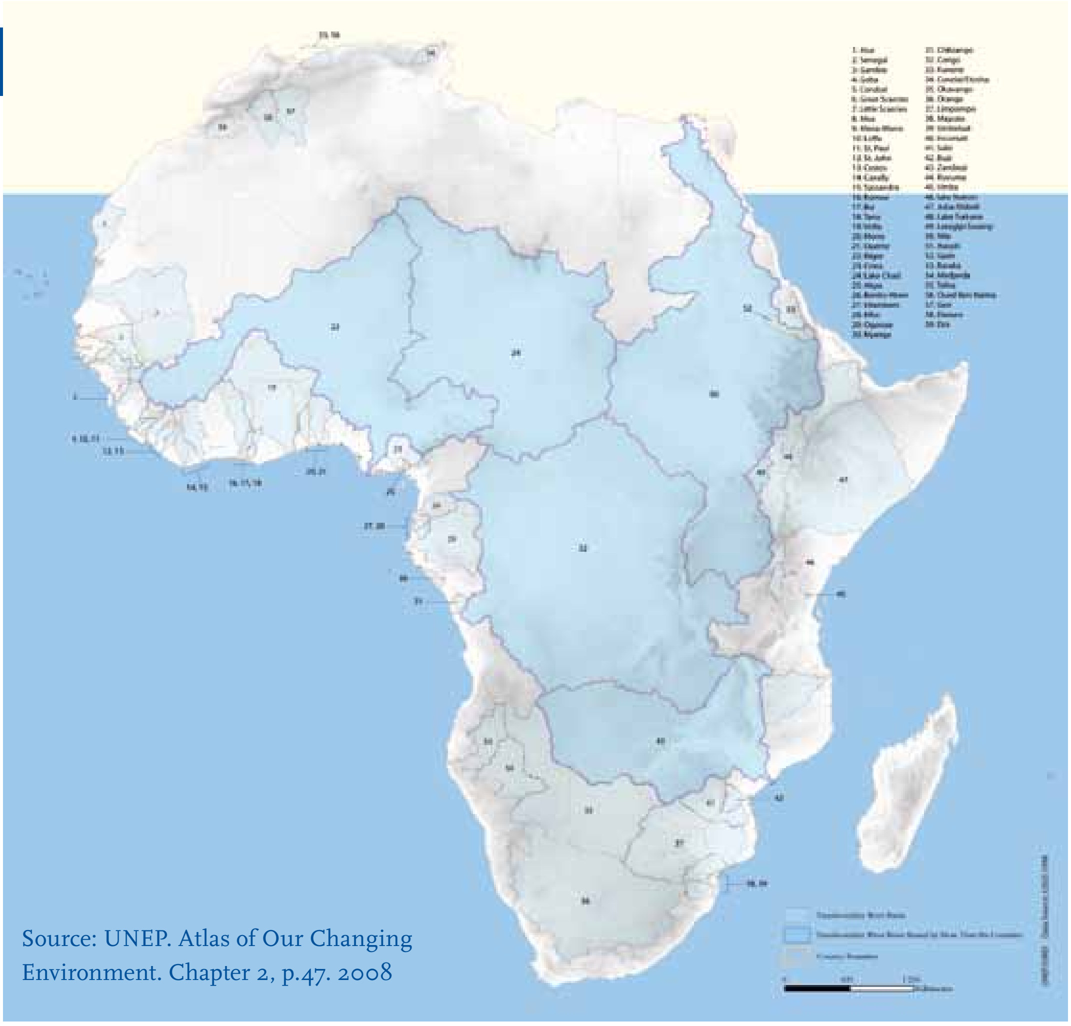
Adaptation is any adjustment that takes place in natural or human systems in response to expected impacts of climate change. It aims at moderating harm or exploiting beneficial opportunities.
Mainstraming is the integration of policies and measures to address climate change into ongoing sectoral planning and management, so as to ensure the long-term viability and sustainability of sectoral and development investments. It is seen as making more efficient and effective use of financial and human resources than designing, implementing and managing climate policy separately from sectoral policies.

Policy Framework for Climate Change Adaptation (CCA)	Ultimate goal is to protect and, when possible, enhance human well-being in the face of climate variability and change
	Development objective is to facilitate the incorporation of adaptation into a country's national development strategy by promoting sustainable policy processes and reducing climate vulnerability
	Operational objective is to provide technical guidance to national climate change teams for developing and assessing climate change adaptation policies and measures

Guiding Principles for CCA	Place adaptation in a development context
	Build on current adaptive experience to cope with future climate
	Recognize that adaptation occurs at different levels in particular, the local (bottom-up)
	Recognize that adaptation will be an ongoing process

Approach to cope with CCA	Link grassroots with national policy-making, utilizing a stake-holder-driven and "bottom-up" approach
	Coordinate with current development policies, priorities and commitments, activities and investments
	Tie together the impact and adaptation aspects of vulnerability assessment
	Integrate assessments across sectors and scales

Expected outputs of a CCA process	Strategy for continuing adaptation process
	Recommendations for adaptation strategies, policies and measures
	Self-sustaining stakeholder process
	Increased national capacity for adaptation assessment



Map 0.1: Transboundary River Basins

From Adaptation Programs to Adaptive Capacity

Adaptation requires amongst others:

- Sound science knowledge and fact-based decision making
- Working with stakeholders searching for integrated solutions
- Public participation active involvement of affected groups; promoting self-help approaches
- Engaged local government actions take place at local level
- Networking and exchange learning from experiences; adapting technical progress
- Tools and mechanism for communication
- Adaptation is a continuous process evolution is adaptation "in practice".

Eventually a shift from "climate change adaptation" programs to "adaptive capacity - for climate change" is required. Adaptive capacity means:

1. Enhanced ability to plan, prepare for and implement adaptation measures
2. Develop factors that determine adaptive capacity of human systems, including economic wealth, technology and infrastructure, information, knowledge and skills, institutions, equity and social capital.

It is clear that "adaptive capacity" cannot be measured directly; rather, it should be seen in the context of a complex technical, political and societal process that requires actions at all levels of decision-making. Actions in the water sector, including transboundary river basin management, are essential for the survival of human society but not exclusive and not in isolation.

This publication seeks to share the African expertise with the aim of enhancing the ability of African River Basin Organisations and countries to adapt to climate change. It provides sufficient evidence to policy makers that action is needed; and at the same time it shows that the capacity to react can be developed by qualified stakeholders in the water sector, if sufficient resources are allocated for planning and implementation.

At the same time it shows the water sector that there are a wealth of opportunities to advance efforts towards sustainable development, and that only integrated approaches to (transboundary) water resources management will be successful in coping with climate change and in developing "adaptive capacity for climate change".

The Entebbe Declaration

Building Adaptive Capacity – Mainstreaming Adaptation Strategies to Climate Change in Managing African Transboundary River Basins

26th – 29th August 2008 | Entebbe Botanical Beach Hotel, Uganda

We, senior officials from shared watercourse institutions in Africa, have participated in an interactive seminar entitled "**Building Adaptive Capacity – Mainstreaming adaptation strategies to climate change in managing African Transboundary River Basins**" held in Entebbe, 26 – 29th August 2008, and as a consequence wish to present the following statement and suggested messages to the African Network of Basin Organisations (ANBO), AMCOW, AMCEN and the African Union Commission.

We, participants, duly recognise that:

- Africa is the continent most vulnerable to climate change, primarily affecting millions of people through extreme events, decreased rainfall and river discharge, and a potential increasing in conflicts.
- The impact of climatic variability and change is undoing development efforts, including slowing the progress towards achieving the millennium development goals.
- Africa has 59 transboundary rivers and lakes covering 64% of the continent's surface area, hosting 77% of the total population who predominantly rely on this resource, making it essential for the river and lake basins to adapt to climate change.
- African communities, river and lake basin organisations have already initiated measures to cope with the impact of changing climatic conditions regarding water, but have achieved limited success due to the magnitude of the challenges.

We are:

Aware of the Addis Ababa Declaration on Climate Change in Africa (January 2007), where the African Union Heads of State and Government committed themselves, inter alia, to integrating climate change into national, sub-regional and regional development policies. We recall that the Chairperson of the African Union Commission was mandated to take a lead role in facilitating Africa's active participation in the climate negotiations.

Cognisant of the high profile and attention given to climate change issues by the African Heads of State during the recent AU Sharm El Sheik Summit (July 2008) during which the heads of state committed themselves to "Put in place adaptation measures to improve the resilience of African countries to the increasing threat of climate change and variability to our water resources and Africa's capacity to meet the water and sanitation targets."

Appreciative of the general commitment and support of Development Cooperation Partners and UN-Water/Africa in building Africa's capacity to adopt suitable adaptive measures in the water sector to cope with water scarcity, climate variability, rainfall uncertainty and increasing vulnerability to climatic change.

Therefore, we:

Agree on the following urgent measures:

- Mainstreaming climate change within the framework of Integrated Water Resources Management (IWRM), taking full consideration of all economic, social and environmental aspects of water;
- Taking stock of and improving our understanding of the vulnerabilities of the transboundary river and lake basins in the context of current and projected climate change;
- Mainstreaming climate change in all lake and river basin organisation development programs and policies to ensure that all development programmes account for climate change;
- Steping up our efforts to implement infrastructural interventions within the basins (dams, reservoirs, diversions etc) within the framework of the African Water Vision 2025;
- Calling on all parties to support the establishment of incentive schemes that promote sustainable ecosystem (forest, land, etc) management within the lake and river basins;
- Building the human, systemic and institutional capacity of the respective river and lake basin institutions in climate change adaptation processes, by promoting South–South and North–South cooperation between basins, as well as interdisciplinary training measures and linkages between national and regional institutions;
- Committing ourselves to work with the civil society, media and the private sector in addressing climate change;
- Actively seeking financial resources from the various available sources to fund climate change adaptation activities within the river basins;
- Developing multi-country plans for adaptation to climate change for all river and lake transboundary basins. In addition, governments and their financial partners should make available resources (financial and human) for the development and implementation of these regional plans;
- Monitoring progress of the implementation of this resolution and report to regional ANBO meetings and the World Water Forum 5;
- Developing a communication strategy to facilitate awareness creation, information packaging and dissemination;
- Adapting mechanisms for the conjunctive use of surface and groundwater resources.

and

Appeal to our governments and our development partners to support and avail extra resources to implement the above and other climate change adaptation programmes.

Policy Brief

Towards a Policy and Climate Change Adaptation for Shared Lake and River Basins in Africa

by Ruhiza Jean Boroto, Regional Water Expert. South Africa

Background and Purpose

A seminar that brought together about 60 delegates from African transboundary river basin organisations, lake authorities, transboundary groundwater aquifers, government, regional development organisations, researchers and NGOs took place in Entebbe, Uganda from 26 to 29 September 2008.

The objective of the seminar was to take stock of the present knowledge on climate change in Africa, to discuss current activities and research findings, and to develop realistic adaptation strategies to manage transboundary river basins under the conditions of climate variability and climate change.

The seminar resolved, amongst other items, to recommend that climate change be mainstreamed in all lake and river basins organization programs and policies and to ensure that all development programmes are climate change proofed.

The purpose of this brief is therefore to trigger action towards the development of policies that respond to this call by (1) identifying which areas such a policy would address and what kind of actions would such a policy seek to foster and (2) proposing what such policy pronouncement should address.

It is a discussion document that stands to be improved with the aim of leading towards the development of appropriate policies for the different institutions concerned, at all levels: Africa continent with the African Ministerial Council on Water (AMCOW), Regional Economic Communities (REC), Shared Lake and River Basin Organisations and countries.

Key areas requiring a policy pronouncement

In the context of Water Resources Management and in particular, shared lakes and river basins in Africa, the following policy intervention areas have been identified as critical to succeeding in developing, adopting and implementing adaptation strategies to climate change.

1. Coordinated actions among countries sharing lakes and river basins

Countries sharing Lakes and River Basins are expected to coordinate their actions towards adapting to climate change. Greater coordination within a Lake or a River Basin will ensure that identified actions are undertaken at the same time. Failure to coordinate actions would defeat the efforts as Adaptation to Climate Change in the context of a shared Lake or River Basin calls for a basin-wide approach.

2. Innovative Awareness Raising

Stakeholders at various levels within shared Lakes and River Basins need to be informed about Climate Change in an innovative fashion that triggers responsible behaviour and appropriate action. Awareness raising will be tailored to the category of stakeholders and should strive to convey the messages in a medium that is easy to understand and trigger a change in behaviour. Such messages should specify actions that are expected from each group of stakeholders in response to Climate Change. A comprehensive communication strategy will have to be developed.

3. Capacity Building and Research Programmes

Capacity Building is a key in combating Climate Change. Countries sharing Lakes and River Basins are expected to initiate capacity building programmes that are tailored to their needs to adapt to Climate Change and would cover areas such as hydrology, meteorology, forestry, land management, etc. The long term benefit is a work force that will assist shared lakes and river basins in implementing adaptive actions in the shared lake and river basins.

Basin-wide research programmes need to be initiated in the different fields that are relevant to climate change. In this respect, collaboration and partnerships with other institutions world wide will be sought in order to maximize the benefits of state of the art science and technology for shared lakes and river basins in Africa. Thus South-South and South-North cooperation should be sought in research on climate change.

4. Sustainable management practices

As far as possible, sustainable management practices should be the norm, rather than the exception. Considering the integrated nature of water resources management, the upstream-downstream inter-dependence, the significance of land use practices, forests on sustainable ecosystem,. The impact of patterns of settlements, etc, a compendium of sustainable management practices aimed at coping with climate change in shared lakes and river basins, should be developed and adopted by shared river basins institutions. Only a critical mass of change in behaviour at all levels could slow down the impact of climate change. Once developed, tested and adopted, the compendium will be used as a guide that will be integrated in policies.

5. Infrastructural interventions

Within the framework of the African Water Vision 2025, efforts to implement infrastructural interventions within the basins (dams, reservoirs, diversions, etc) should be stepped up. Their role should be to reduce vulnerability to climate change through the provision of storage during droughts and as a mitigation measure to cope with floods.

Cooperation between co-basin states in shared lakes and river basins will be a condition to these infrastructure interventions with the objective of achieving equity in sharing the resulting benefits.

6. Adaptive measures

Appropriate adaptive measures need to be implemented as a priority. One such measure is the conjunctive use of surface and groundwater which, in the context of climate change, will increase the capacity to cope. This calls for a concerted effort among co basin states of shared lakes and river basins to investigate the potential of groundwater within their basins as another source of water supply. This would heed the resolution of the AMCOM on groundwater.

Similarly, drought resistant crops should be promoted and other practices, such as, water conservation and water demand management in shared lake and river basins encouraged.

A comprehensive inventory of adaptive measures should be undertaken and be part of the above proposed compendium of good practices to adoption by member states.

7. Monitoring and Early Warning Systems

Monitoring of key meteorological and hydrological parameters of climate change indicators should be done systematically with the view of constituting a database that would assist scientists in future analyses, leading to informed decision making. Such parameters include temperature, rainfall, evaporation, lake levels and flows in rivers. Prediction of floods and droughts at local and macro scale levels should be undertaken.

Early Warning Systems within shared lake and river basins should be put in place to enable countries to take necessary measures to protect vulnerable communities and mitigate or reduce the impact of climate change related disasters.

8. Comprehensive multi-country action plans

All the above calls for countries within a shared lake or river basins to develop comprehensive multi-country adaptation action plans which take into account the needs of the basin as a whole while acknowledging the specific context of each country. Such plans should provide identify the responsibilities, resources required and a monitoring and evaluation mechanism within defined time frames.

9. Funding

A fund dedicated to the implementation of the comprehensive multi-country action plans mentioned above needs to be established for each shared Lake and River Basin. A strategy for fund raising through co-basin member states contributions and/ or International Cooperating Partners will be developed.

10. Institutional Preparedness

It is important that a coordinated institutional mechanism is established at different levels to take responsibility for developing and implementing the proposed policy actions. While the prime responsibility at Africa level lies with AMCOW, REC bodies such as Economic Community of West African States (ECOWAS), Southern African Development Community (SADC) need to equally to prepare an institutional response through dedicated units. Critically, all Lake and River Basin Organisations need to establish their own units that will take forward these policy recommendations for implementation within each co-basin state.

3. Proposed process towards developing and implementing policies

This brief has been prepared to trigger action towards the development of policies that seek to promote and facilitate the adaptation to climate change for shared lakes and river basins in Africa.

It is proposed that it is further discussed at the different levels (AMWCOW, RECs and Lake and River Basin Organisations). The objective would be (1) to adopt the brief after amendments and (2) to develop an implementation strategy (a) from the brief to a proper policy and (b) from the policy itself to its roll out with time frames and institutional roles and resources defined on each policy item.

Chapter 1

Climate Change Scenarios

Impacts and Adaptation Strategies in Africa

By Datius G. Rutashobya. Climate and Water Department. World Meteorological Organization. Geneva, Switzerland

Contents

1. Introduction

1.1 Climate change

Climate change and its impacts are of great concern to humanity and is one of the most serious problems facing sustainable development worldwide. It is now generally acknowledged that the global climate is changing, as the earth becomes warmer. Climate change may be considered any long-term significant change in the “average weather” that a given region experiences. Average weather may include average temperature, precipitation and wind patterns.

The Intergovernmental Panel on Climate Change (IPCC) refers to climate change as a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. These changes can be caused by dynamic processes on earth, external forces including variations in sunlight intensity and more recently by human activities.

Recent effort in climate change studies has been directed towards scientifically defining the mechanisms responsible for relatively recent changes observed in the earth’s climate. The effort has focused on changes observed during the period of instrumental temperature recording, the period with the most reliable records; and particularly on the last 50 years, when human activity has grown fastest and observations of the upper atmosphere have become available. The dominant mechanisms to which recent climate change has been attributed all result from human activity (Figure 1.1).

They are:

- increasing atmospheric concentrations of greenhouse gases
- global changes to land surface, such as deforestation
- increasing atmospheric concentrations of aerosols.

Radiative Forcing Components

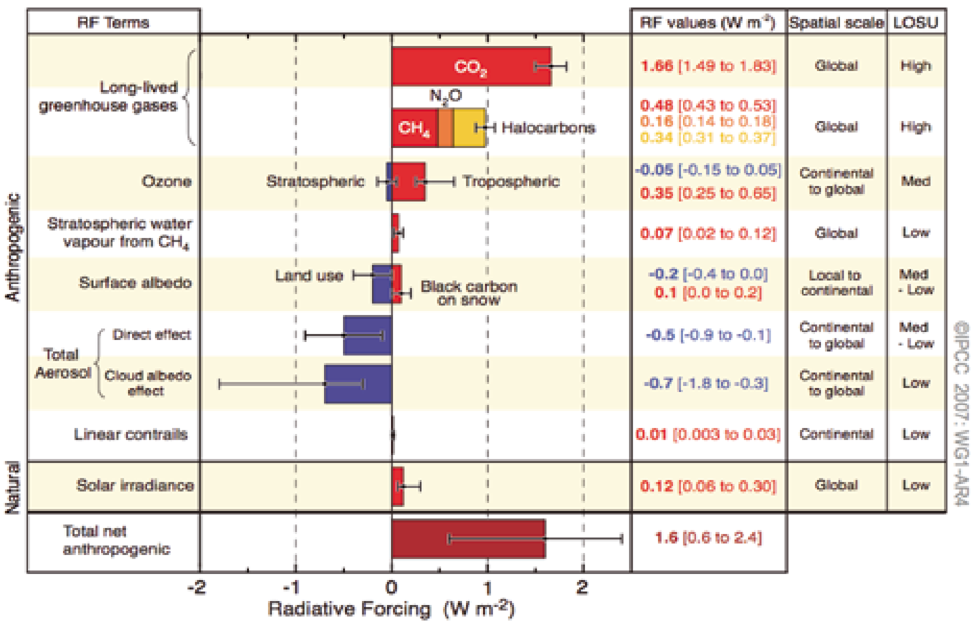


Figure 1.1: Human and natural drivers of climate change

Carbon dioxide is causing the bulk of the forcing.

On average, it exists more than a hundred years in the atmosphere and therefore affects climate over long time scales.

Recent reports from the IPCC have concluded that:

- „Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."
- „From new estimates of the combined anthropogenic forcing due to greenhouse gases, aerosols and land surface changes, it is extremely likely that human activities have exerted a substantial net warming influence on climate since 1750."
- „It is virtually certain that anthropogenic aerosols produce a net negative radiative forcing (cooling influence) with a greater magnitude in the Northern Hemisphere than in the Southern Hemisphere. Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism."

Climate Change – an integrated framework

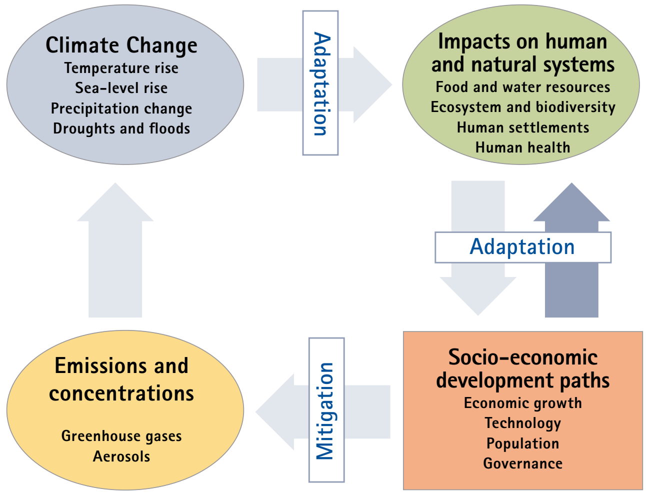


Figure 1.2: Climate Change - an integrated framework

1.2 Greenhouse gases – Current trends

The radiative forcing of the climate system is dominated by the long-lived greenhouse gases (GHGs). Due to the industrial revolution, human activities are increasing the atmospheric concentrations of GHGs – which tend to warm the atmosphere – and, in some regions, aerosols – which tend to cool the atmosphere. These changes in GHGs and aerosols, taken together, are projected to lead to regional and global changes in climate and climate-related parameters such as temperature, precipitation, soli moisture and sea level.

The current concentrations of key GHGs, and their rates of change, are unprecedented. Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. Scientific consensus has identified carbon dioxide as the dominant greenhouse gas forcing. (Water vapour is the dominant greenhouse gas overall; however, it has a very short atmospheric lifetime of about 10 days and is very nearly in a dynamic equilibrium in the atmosphere, so it is not a forcing gas in the context of global warming). Methane (CH4) and nitrous oxide (NO2) are also major forcing contributors to the greenhouse gas effect.

Carbon dioxide (CO2) is the most important anthropogenic GHG. The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005 (Figure 1.3). This exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores. During the 10 year period 1995–2005, the annual carbon dioxide concentration growth-rate was 1.9 ppm per year; the largest level since the beginning of continuous direct atmospheric measurements. The average for the period (1960 – 2005) was 1.4 ppm per year. CO2 increases are mainly due to fossil fuel burning.

Annual fossil carbon dioxide emissions increased from an average of 6.4 gigatonnes of Carbon (GtC) per year in the 1990s, to 7.2 GtC per year in 2000–2005.

The global atmospheric concentration of methane increased from a pre-industrial value of about 715 ppb to 1732 ppb in the early 1990s, and was 1774 ppb in 2005. The atmospheric concentration of methane in 2005 exceeds by far the natural range of the last 650,000 years (320-790 ppb), as determined from ice cores.

The global atmospheric nitrous oxide concentration increased from a pre-industrial value of about 270 ppb to 319 ppb in 2005.

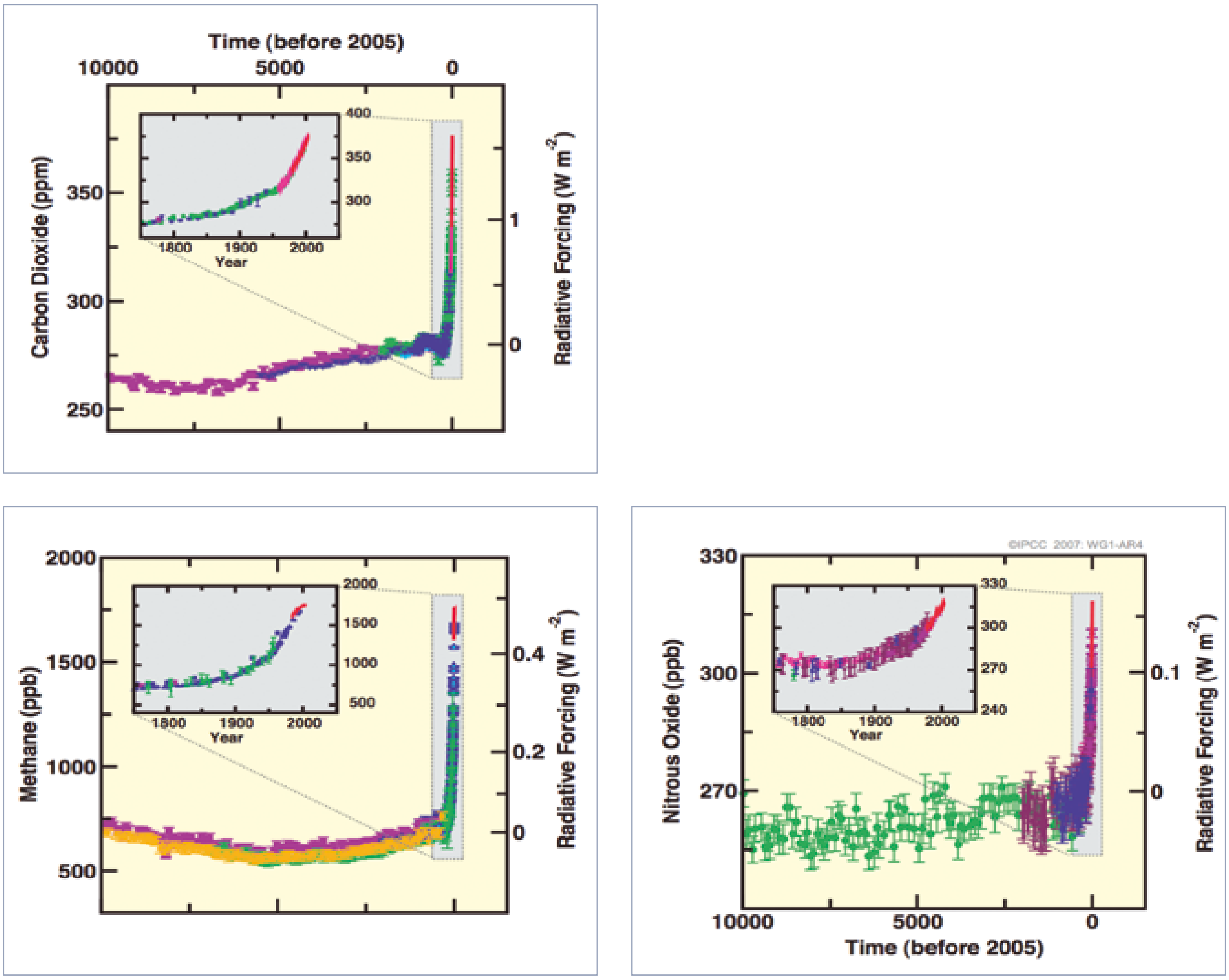


Figure 1.3: Greenhouse gas concentrations

2. Climate change

2.1 Some current facts

Observed warming over several decades has been linked to changes in the large-scale hydrological cycles such as increasing atmospheric water vapour content; changing precipitation patterns, intensity and extremes; reduced snow cover and widespread melting of ice; and changes in soil moisture and runoff.

Warming of the climate system is unequivocal; as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level. As indicated in Figure 1.4, global mean surface temperatures have increased, the land and oceans have warmed. According to the IPCC (2001), the global average surface temperature increased over the 20th century by about 0.6°C and temperatures have risen in the past four decades in the lowest eight kilometers of the atmosphere. Eleven of the last twelve years (1995–2006) rank among the 12 warmest years since the instrumental recording of global surface temperature began in 1850. The linear war-

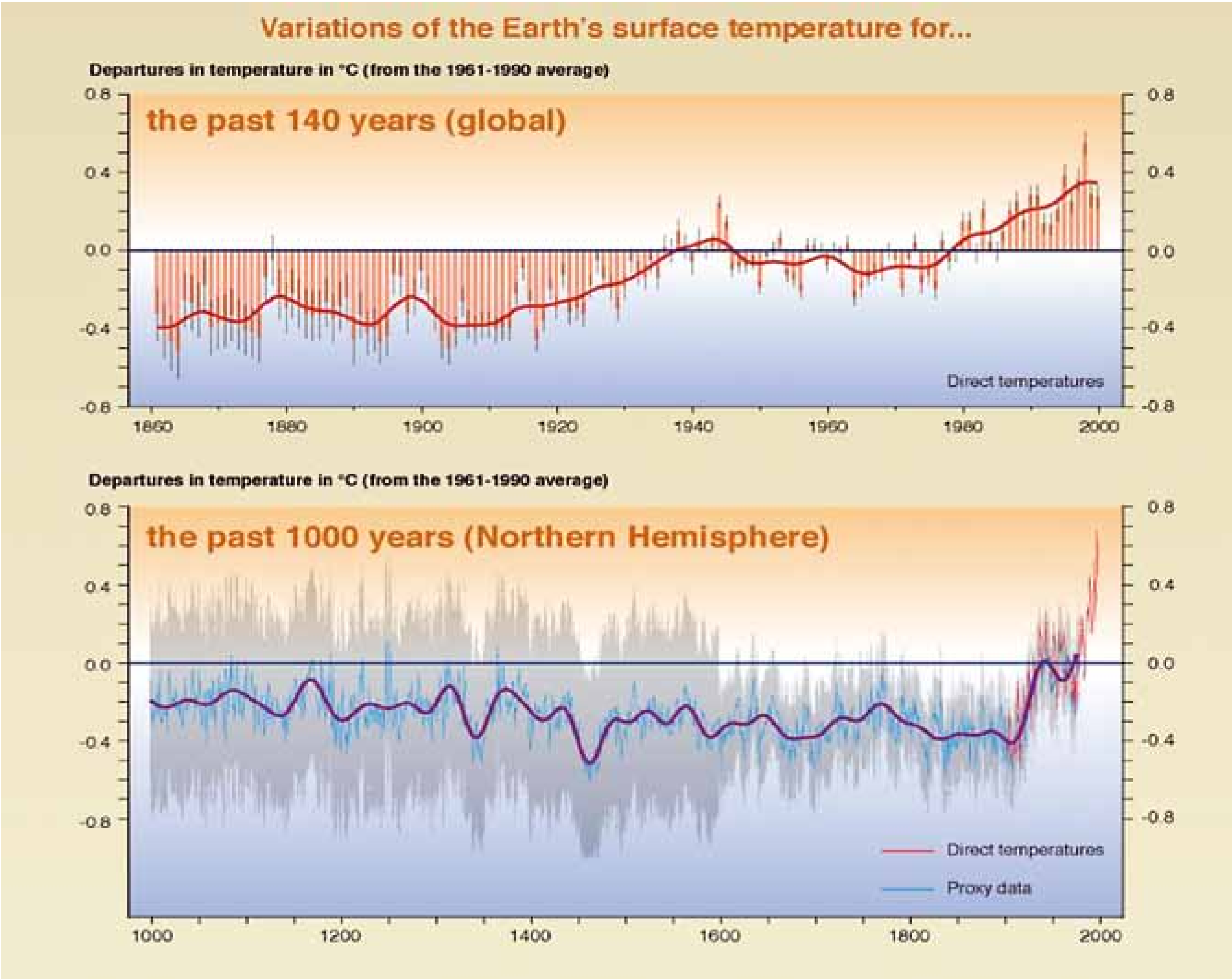


Figure 1.4: Variation of the earth's surface temperature

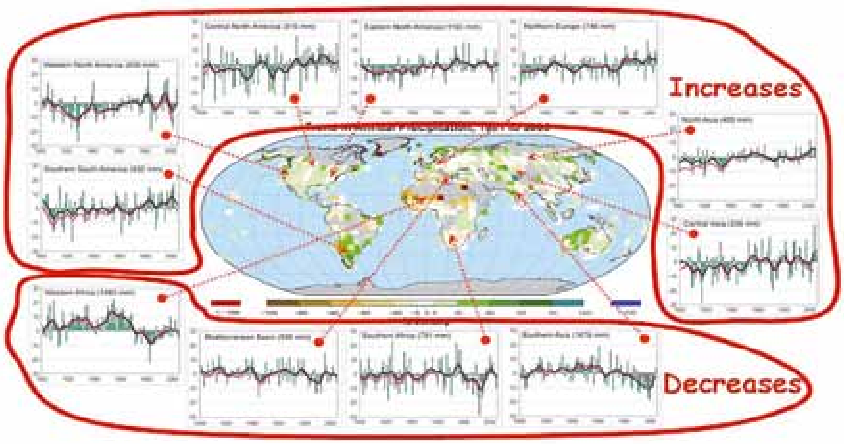


Figure 1.5: Land precipitation is changing significantly over broad areas: Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability

ming trend over the last 50 years (0.13 °C per decade) is nearly twice that for the last 100 years. Observations since 1961 show that the average temperature of the global oceans has increased to depths of at least 3000m and that the ocean have been absorbing more than 80% of the heat added to the climate system (IPCC, AR4).

Land precipitation is changing significantly over broad areas. The frequency, persistence and magnitude of El-Nino events have increased in the last 20 years (Figure 1.6). The El-Nino phenomena lead to floods and droughts throughout the tropics and subtropics. Floods events have increased and many dry areas are getting drier with devastating consequences.

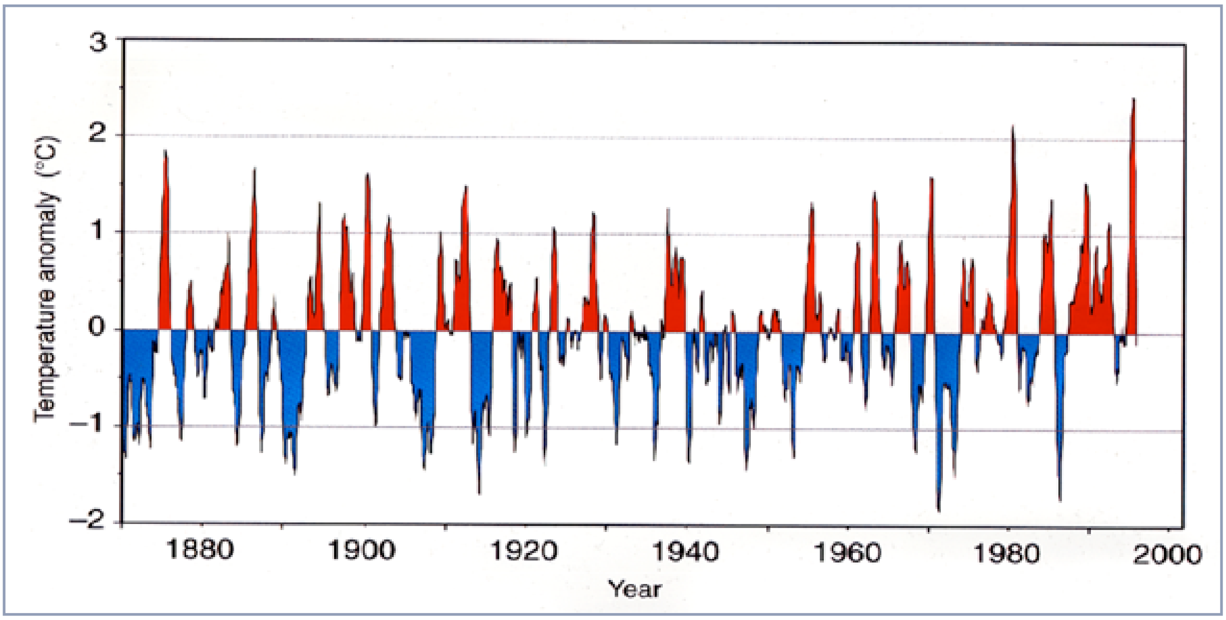
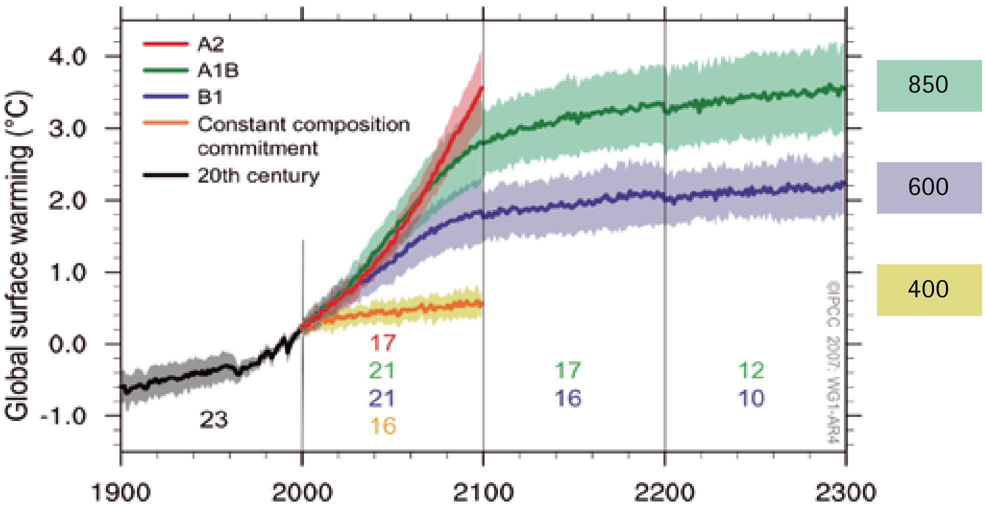


Figure 1.6: Frequency, persistence and magnitude of El-Nino events



Warming will increase if GHG increase. If GHG were kept fixed at current levels, a committed 0.6°C of further warming would be expected by 2100. More warming would accompany more emission.

Figure 1.7: What's in the pipeline and what could come

2.2 Climate change in Africa

Major drivers of African climate variability are El Niño-Southern Oscillation (ENSO) and land cover change. The African continent is warming at a faster rate than the global average. Historical records indicate a warming trend in the temperature over Africa of approximately 0.7°C during the 20th century. An average decrease in rainfall of some 25% has occurred over the Africa Sahel during the past 30 years with consequences that include recurrent droughts (Figure 1.8).

Climate change is not a crisis of Africa's making, yet, according to a review on the economics of climate change conducted in November 2006, it is African people, especially the poorest, who will suffer the earliest and the most. Reports by the IPCC and UNDP show that climate change could have devastating impacts on African development particularly in the following areas:

Figure 1.8: Effects of drought in Africa

- Agricultural Productivity: The areas suitable for agriculture, the length of growing seasons and the yield potential of food staples are all projected to decline. Some African countries could see agricultural yields decrease by 50% by 2050 and net crop revenues could fall by as much as 90% by 2100.

- Water Security: Rising temperatures can alter runoff patterns and increase water evaporation rates, which can severely reduce the availability of water. By 2020, an additional 75-250 million people in Africa are projected to be exposed to increased water stress due to climate change.

- Rising Sea Levels: Towards the end of the 21st century, the projected sea level rise around Africa will affect low-lying coastal areas with large populations. Highly productive ecosystems, which form the basis for important economic activities such as tourism and fisheries, are located in coastal zones.
- Human Health: Climate change will affect human health through complex systems involving changes in temperature, exposure to extreme events, access to nutrition, air quality and other vectors. For example, climate change threatens to increase the range and transmission potential of malaria.

- Ecosystems and Biodiversity: Changes induced by climate change are likely to result in species range shifts and changes in tree productivity, adding further stress to forest ecosystems. Studies predict that 25–40% of mammal species such as zebra could become endangered or extinct by 2080 and that 5,000 African plant species will be faced with substantial reductions in areas suitable for growth by 2085.

3. Climate change – Future projections

The increase in greenhouse gases in the atmosphere due to anthropogenic activities is expected to be the most important factor forcing climate to change during the 21st century. If GHG remain fixed at current levels, a further warming of some 0.6°C would be expected by 2100 (IPCC 4AR). There is high agreement and much evidence, however, that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to increase over the coming decades. Projected concentrations of CO2 during the 21st century are two to four times the pre-industrial level (Figure 1.9). Based on the range of sensitivities of climate to increases in greenhouse gas concentrations reported by IPCC and plausible ranges of emissions, climate models project an increase in global mean surface temperature of about 1.8–4.00C by 2100. This projected rate of warming is much larger than the changes observed during the 20th century and is without precedent during at least the last 10,000 years. The global mean sea level is projected to rise by 0.18 to 0.59 metres.

Past and future CO2 atmospheric concentrations

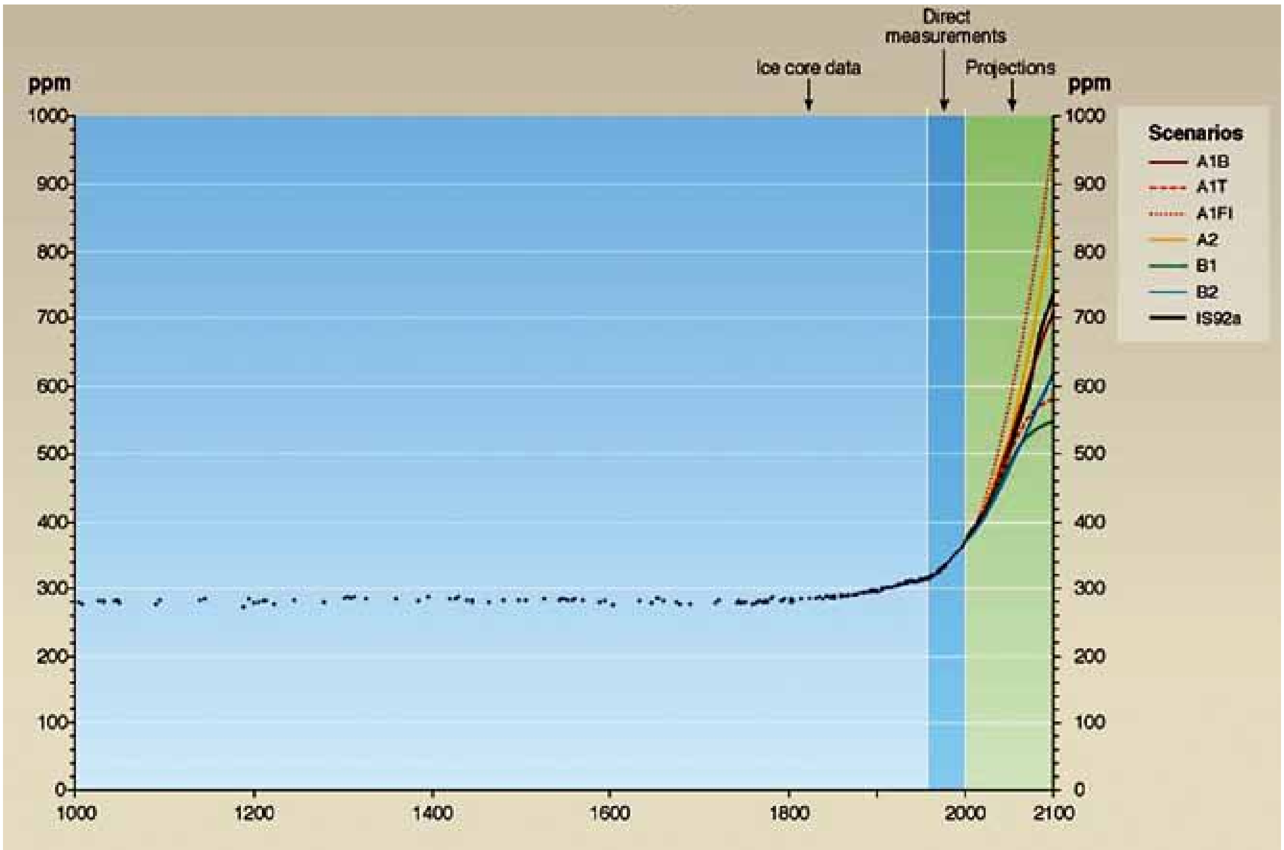


Figure 1.9: Projected atmospheric CO_2 concentrations

4. Impacts of Climate Change on Water Resources

Figure 1.10: Water scarcity

4.1 The global picture

Climate change impacts on freshwater resources affect sustainable development and endangers economic development, poverty reduction strategies, child mortality reduction programs, production and availability of food and the health of people and ecosystems. Water resources are inextricably linked with climate, many water systems being sensitive to climate change and some are currently vulnerable; consequently, the prospect of global climate change has serious implications for water resources and regional development. Therefore, both climate change and climate variability must be addressed to assure water security on the continent. Both droughts and floods have increased in frequency and severity over the past 30 years. Climate change is projected to decrease water availability in many arid- and semi-arid regions. One third of the world's population is currently subject to water scarcity and the population facing water scarcity will more than double over the next 30 years.

Climate change will lead to an intensification of the global hydrological cycle and could have major impacts on regional water resources. A change in the volume and distribution of water will affect both ground and surface water supply for domestic and industrial uses, irrigation, hydropower generation, navigation, instream ecosystems and water-based recreation (IPCC, 1996). Although some of the principal links between climate and the hydrological cycle are well understood, predicting the effects of global warming is very uncertain.

The IPCC report indicates a decrease in precipitation occurring during the 1900s, and particularly after the 1960s, over the subtropics and the tropics. Changes in the total amount of precipitation and in its frequency and intensity directly affect the magnitude and timing of runoff and the intensity of floods and droughts. Higher latitude regions may experience increased runoff due to increased precipitation, whereas runoff may decrease at lower latitudes due to the combined effects of increased evapotranspiration and decreased precipitation. More intense rainfall would tend to increase runoff and the risk of flooding, although this would depend not only on the change in rainfall but also on the physical and biological characteristics of the catchment in question.

Climate change is expected to exacerbate current stresses on water resources from population growth and economic and land-use change, including urbanization. On a regional scale, mountain snow pack, glaciers and small ice caps play a crucial role in freshwater availability. Widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century, reducing water availability, hydropower potential and changing seasonality of flows in regions supplied by melt water from major mountain ranges (e.g. Hindu-Kush, Himalaya, Andes), where more than one-sixth of the world population currently lives.

The IPCC Fourth Assessment Report indicates runoff is projected with high confidence to increase by 10 to 40% by themiddle of the 21st century at higher latitudes and in some wet tropical areas, including populous areas in East and South-East Asia, and decrease by 10 to 30% over some dry regions at mid-latitudes and dry tropics, due to decreases in rainfall and higher rates of evapotranspiration. There is also high confidence that many semi-arid areas (e.g. the Mediterranean basin, western United States, southern Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change. Drought-affected areas are projected to increase in extent, with the potential for adverse impacts on multiple sectors, e.g. agriculture, water supply, energy production and health.

Available research suggests a significant future increase in heavy rainfall events in many regions, including some in which the mean rainfall is projected to decrease. The resulting increased flood risk poses challenges to society, physical infrastructure and water quality. It is likely that up to 20% of the world population will live in areas where the river flood potential could increase by the 2080s. Increases in the frequency and severity of floods and droughts are projected to adversely affect sustainable development. In coastal areas, sea level rise will exacerbate water resource constraints due to increased salinization of groundwater supplies.

4.2 Impacts on Africa

Africa has contributed less than any other region to the greenhouse gas emissions that are widely held responsible for global warming. Africa represents 11% of the world's population but accounts for just 3% of the world's greenhouse gases emissions – the lowest per capita emissions in the world (World Resources Institute, 2007). However, new studies confirm that Africa is one of the most vulnerable continents to climate variability and change. Africa, like most of the developing world, has lower capacity to adapt to climate change owing to a lack of financial, institutional and technological capacity and access to knowledge.

The major impact of climate change and variability on the water resources of Africa will be through the changes in the hydrological cycle, the balance of temperature and rainfall. A range of climate scenarios projected that Africa would suffer an amplified water stress and an increase of 5-8% of arid and semi-arid land by the end of the 21st century. By 2050 the area experiencing water shortage in sub-Saharan Africa will increase by 29%. Some of the major impacts of climate change on water resources in Africa are likely to encompass the following (AfDB et. al. 2002):

(a) Increase in drought, flood, windstorms and other extreme climate phenomena will negatively affect water resources through reduced freshwater availability, food security, human health, industrial production and weakened physical infrastructure base for socio-economic activity;

(b) Changes in rainfall (including likely wetting in east Africa and drying in southeast Africa) and more intense land use will result in increased deforestation, loss of forest quality and woodlands degradation across the continent which will worsen the situation as regards desertification (particularly in west, northern and southern Africa);

(c) Sea level rises leading to coastal erosion and flooding, particularly in West, East and North Africa, and bleaching of coral reefs along the Red sea and Indian Ocean coastal zone. The expected sea level rises will also cause salt water intrusion further inland thus affecting fresh groundwater resources in coastal areas of Africa. With more than one-quarter of the population living within 100 km of the coast and most cities concentrated along the coastline, the vulnerability to marine-induced disaster from tidal waves and storm surges will increase;

(d) The decrease in river basin runoff and water availability for agriculture and hydropower generation due to changes in rainfall and river sensitivity to climate variation will likely result in increased cross-boundary tensions. This will result in more conflicts, intensification of existing conflicts or reduced ability to resolve them.

14 African countries are already experiencing water stress; another 11 countries are expected to join them by 2025. By 2020, an additional 75-250 million people in Africa are projected to be exposed to increased water stress due to climate change (IPCC, 2007). Across the Horn of Africa, forced adaptation to climate change is already occurring as women walk further to find water in the dry season. In northern Kenya, which has experienced a steady decline in mean annual rainfall over the last 50 years, the increased frequency of droughts means that women are walking greater distances to fetch water, often ranging from 10 to 15 kilometers a day (UNDP, 2008).

Towards the end of the 21st century, projected sea level rise around Africa will affect low-lying coastal areas with large populations IPCC, 2007). In total, 70 million people and 30% of the Africa's coastal infrastructure could face the risk of coastal flooding by 2080 because of rising sea levels (UNFCCC, 2006). It has beendeduced through modelling that a one meter rise in sea level in the Atlantic will have damaging impacts on societies in Africa and large cities such as Banjul, Lagos, Alexandria, Dar es Salaam, Cape Town or Maputo are at risk of becoming submerged.

Africa has been impacted by more than 30% of all water-related disasters during the last ten years. Specific observed impacts include: Shrinking of Lake Chad and Lake Turkana; fluctuation of water levels of Lake Victoria; melting snow of Mount Kilimanjaro. Further, the flows of major rivers and the water levels in the 160 lakes in Africa will reduce.

5. Adaptation strategies

5.1 General

The adaptation strategy for a country, a basin, or part thereof, refers to a general plan of action for addressing the impacts of climate change, including climate variability and extremes. It includes a mix of policies and measures with the overarching objective of reducing the country's vulnerability (UNDP, 2004). Adaptation practices refer to actual adjustments, or changes in decision environments, which might ultimately enhance resilience or reduce vulnerability to observed or expected changes in climate (IPCC, 2007).

Societies have a long record of adapting to the impacts of weather and climate through a range of practices that include crop diversification, irrigation, water management, disaster risk management and insurance. But climate change poses novel risks often outside the range of experience, such as impacts related to drought, heatwaves, accelerated glacier retreat and hurricane intensity. Adaptation measures that also consider climate change are being implemented, on a limited basis, in both developed and developing countries. These measures are undertaken by a range of public and private actors through policies, investments in infrastructure and technologies and behavioural change. Nevertheless, additional adaptation measures will be required at regional and local levels to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades.

Adaptations are expensive and the level of technological and economic development of a country determines the extent to which countries can cope with climatic changes.

5.2 Integrated approach for adaptation to the impacts of climate change on water resources

Adaptation of water management to climate change implies balancing water demands and resources in an uncertain and changing situation. Climate scenarios are developed to describe different possible futures, based on certain choices and assumptions about greenhouse gas emissions. Scenarios are alternative images of how the future might unfold and are an appropriate tool for analyzing how driving forces may influence future emissions and for assessing associated uncertainties. Climate scenarios and models support water management in the light of climate change, by describing the steps involved in the process of developing scenarios and using models for prediction.

Global Climate Models (GCMs) are mathematical models used to simulate both the present climate and the projected future climate changes. GCMs estimate the effect that emissions have on global climate. They describe important physical elements and processes in the atmosphere and oceans and on the land surface that make up the climate system. Typically, a GCM has a resolution of a few hundred kilometres. Regional climate models (RCMs) provide similar information, only at a smaller resolution. RCMs are therefore more suitable for developing adaptation strategies at the river basin level (Figure 1.11).

To conceptualize and investigate the link between climate and water resources, it is necessary to combine GCMs and hydrological models. Figure 1.12 provides an overview of how data, scenarios and models are used to develop an adaptation strategy to climate change.

The developed scenarios, together with the forecasted data from the climate models, are the basic input for hydrological models. These models calculate the hydrological responses to rainfall based on local characteristics such as soil characteristics, the type and density of vegetation cover and land-use characteristics. Finally, the models provide output on the future hydrological conditions in a river basin. The model output includes information on available water resources as well as water demands, thus providing background information for assessing the vulnerability in a basin.

5.3 Adaptation strategies in Africa

Developing countries, especially the least developed countries (LDCs) and Small Island Developing States (SIDS) are highly vulnerable to the impacts of climate change and climate variability. Their needs for adaptation, as is the case for all countries, should be coordinated with social and economic development in an integrated manner. Countries also need to incorporate local and indigenous knowledge in their activities related to impacts, vulnerability and adaptation to climate change.

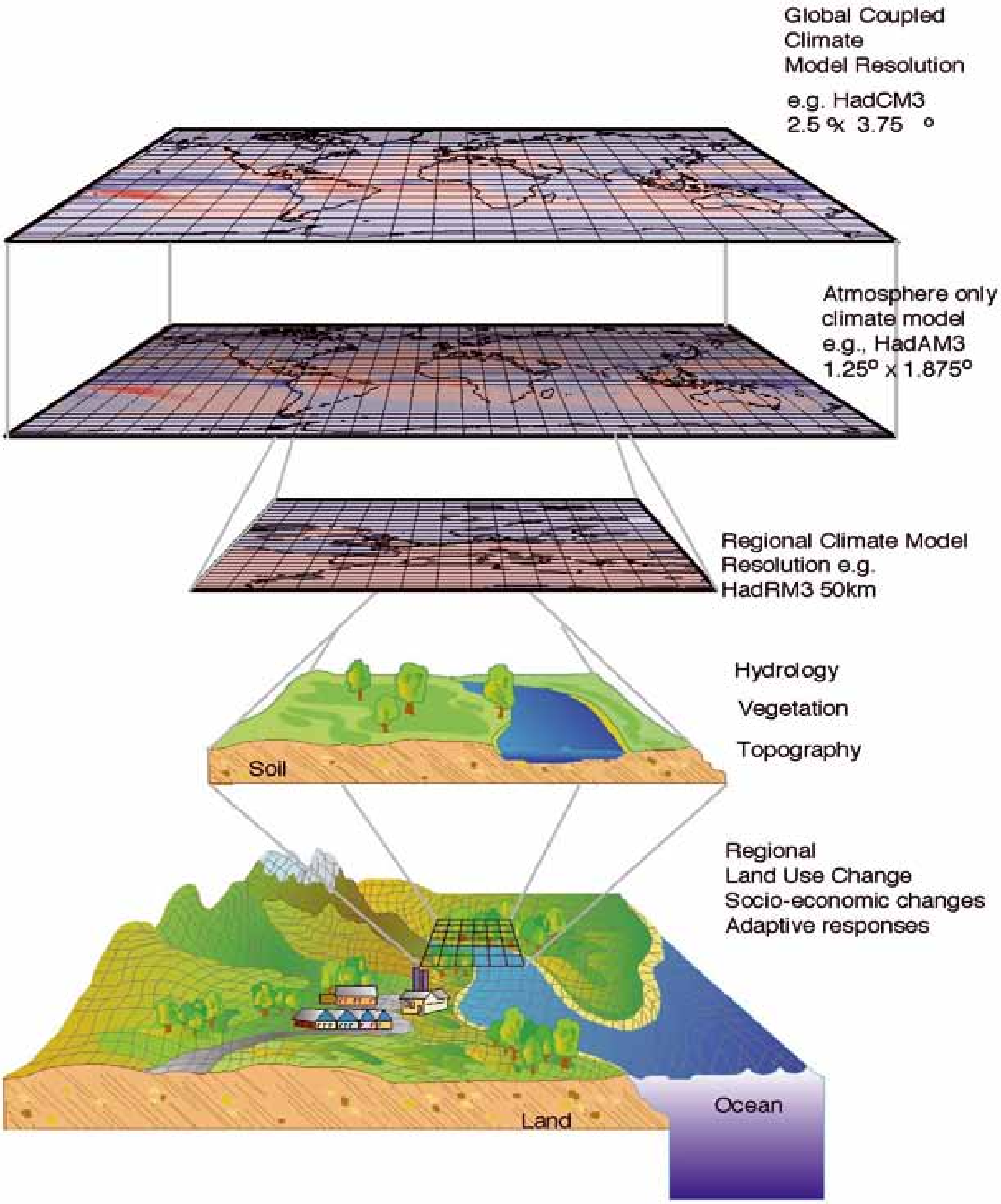


Figure 1.11: GCMs to Regional Adaptive Responses: Regional Climate Models (dynamical downscaling) or Multiple linear regression,artificial neural networks(ANN)(statistical downscaling)

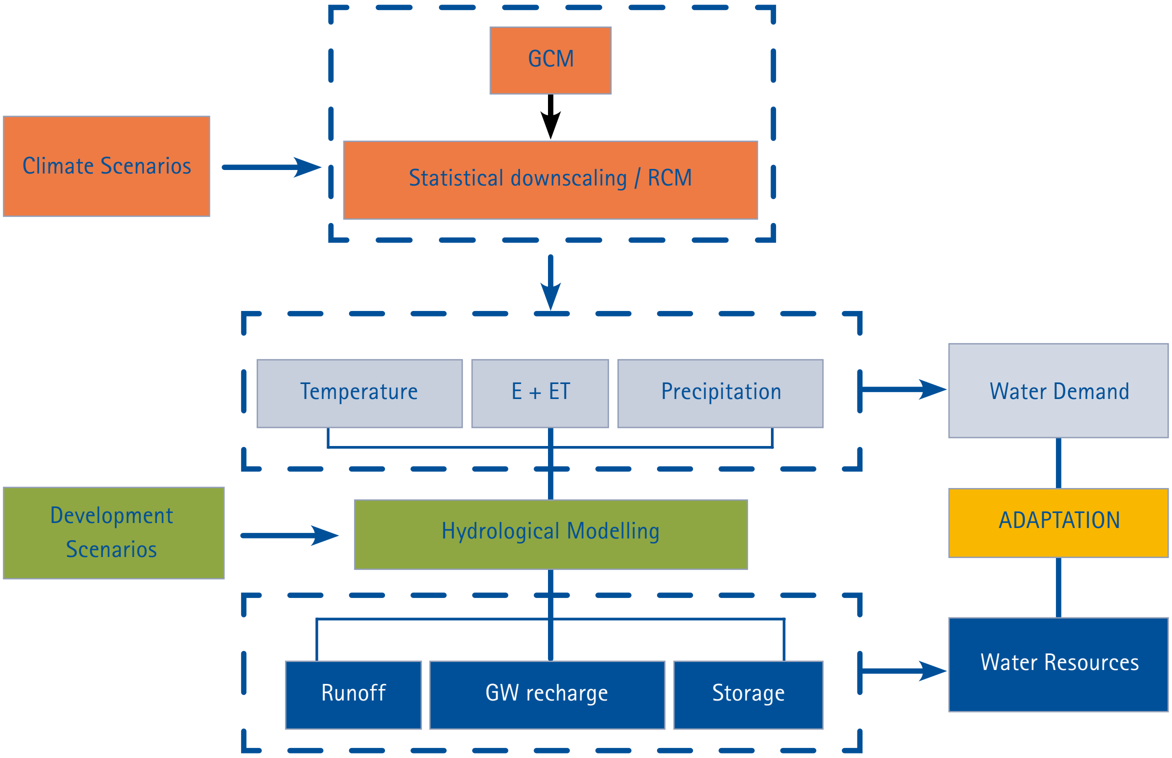


Figure 1.12: Scenarios, data, models and adaptation strategies

Africa is highly vulnerable to climate change in terms of human security and development. The region is characterized by the low adaptive capacity, mainly due to the chronic poverty conditions over many African counties, lack of basic information and lack of appropriate political, technological and institutional framework. These problems are compounded by frequent natural disasters (e.g. droughts and floods), heavy dependency on rainfed agriculture, settlements in vulnerable areas and macro and micro-structural problems. Hence, focus on increasing adaptive capacity over the long term is considered critical in responding to the impacts of climate change and offers opportunities to support sustainable development. Adaptation strategies are going to be of crucial importance in this respect; and can range from traditional to new technologies.

Most of Africa's water resources are transboundary. About half of the 64 transboundary rivers are shared by three or more riparian countries; ten basins are shared by four or more countries. Hence, transboundary water resources management is essential. This calls for formation of river basin institutions and sharing and exchanging transboundary water information.

Africa should deepen regional partnerships over water use infrastructure, cooperate over shared water resources, and look for opportunities to invest in infrastructure of regional importance. It is also important to coordinate actions on climate change and climate variability at the regional level in close cooperation with River Basin Organisations (RBOs). Regional cooperation protocols are needed to minimize both adverse impacts and the potential for conflicts, particularly in arid and semi-arid regions. Countries should pursue transboundary and regional opportunities for sharing water infrastructure of regional importance.

Below are some of the specific adaptation measures that the water sector in Africa need to undertake to cope with future climate change.

a) Efficient water use and water recycling. In view of the water scarcity resulting from climate change, water will have to be used efficiently so that it may, at least, suffice for the basic needs. Wherever possible, water may have to be recycled.

b) Operationalization of Integrated Water Resources Management (IWRM) principles of optimizing water resources development for economic, social and environmental needs. Application of optimization models in the management of water resources is important, particularly in major river basins, to ensure the most optimal way of allocating and utilizing limited water resources.

c) Conjunctive use of surface and groundwater. Optimal utilization of water resources by using groundwater and surface water in a balanced way depending on the availability is a necessity in mitigating the impact of climate change.

d) Early warning. Cooperation in the development of effective early warning systems for water-related disaster prevention and mitigation will have to be promoted to reduce the negative impacts of climate change on economic development, food security and poverty eradication. Drought Monitoring Centres will have to be used to inform farmers with respect to onset of rainy season.

e) Rainwater harvesting. There is currently limited application of rainwater harvesting (RWH), despite its high potential for alleviating the impacts of climate change in many areas of Africa; and the fact that RWH technology is easy to use. There is a real need to create awareness, mobilize and sensitize all leaders, water users and practioners at all levels to the benefits of the technology. RWH needs to be mainstreamed into policy. Governments and donors should be encouraged to invest more in rainwater management.

f) Groundwater development. Groundwater is used by more than 75 per cent of the population in Africa (Matondo, 2008), mainly in the North African countries such as Libya, Tunisia and parts of Algeria and Morocco, as well as in some Southern African countries. Groundwater represents 15 per cent of Africa's water resource with the major aquifers located in arid zones of the northern Sahara, Nubia, Sahel, Chad Basins and Kalahari. Africa's groundwater resources are available as extensive and deep regional aquifers, as locally important high-yielding sources and as lower-yielding but widespread resources on the Basement Complex. They are a resource that is vital to water security. Unfortunately, they are over-exploited in some locations and massively underused in others. There is a need to harness local groundwater resources to improve livelihoods and manage risks associated with climate change. It is also important to institutionalise dialogue on groundwater management in Africa and implement the Roadmap for the African Groundwater Commission.

g) Construction of water storage and inter-basin water transfer facilities. Storage facilities need to be constructed to store water during times when it is available in plenty, to be used when there is less or no water. Inter-basin water transfer involves the transfer of water from basins considered to have surplus water to those where the demand for water has exceeded or is expected to exceed supplies. One example is the planned Oubangui-Lake Chad Water Transfer.

h) Mainstreaming climate change adaptation options/strategies in national development action plans. Strategies and options for climate change adaptation need to be considered when preparing national development action plans.

i) Application of IWRM principles. Sustainable management of water resources has to be carried out through Integrated Water Resources Management (IWRM) principles, rather than through a fragmented approach.

j) Flood zoning has to be carried out in low lying areas which are prone to flooding in order to protect the population and the environment from flood damage, encourage responsible development and prevent the degradation and deterioration that results from unrestricted use and development.

k) Joint management of international waters needs to be addressed at scientific, administrative and political levels. It is important to strengthen regional partnerships over water use infrastructure, cooperate over shared water resources and look for opportunities to invest in infrastructures of regional importance. It is necessary to encourage and give support to the formation of transboundary joint-ventures and other partnership arrangements between national/regional and foreign firms to promote transfer of technology and know-how.

l) Hydrological data and water information. Good and accurate information aids decision-making and enables better choice and design of infrastructure. In order to ensure water security, data and information on quantity and quality of available freshwater is crucial for the planning and efficient and sustainable water resources development and management in Africa. The status of the hydrological network in Africa is generally inadequate to satisfy the minimum needs for information. Climate change adaptation strategies for the future require hydrological data and information to enable assessment of the impacts of climate change on water resources at basin scale. There is therefore a need to sensitize decision makers on the importance of hydrological data and water information.

m) Support to African scientists. African scientists need to be supported in establishing sound scientific principles for developing effective adaptation measures against impacts of climate change.

6. WMO's contributions

6.1 WMO's mandate and role

The World Meteorological Organization (WMO) is the United Nations system's authoritative voice on the state and behavior of the earth's atmosphere including its interaction with the oceans, the climate and water resources. It provides world leadership in expertise and international cooperation in weather, climate, hydrology and water resources, and related environmental issues, and thereby contributes to the safety and well being of people throughout the world and to the economic benefit of all nations.

WMO's strategies have been designed to respond to a number of challenges related to weather, climate and water issues. WMO has a vast reservoir of expertise, knowledge, data and tools among its members, programmes and technical commissions, as well as through its partnerships.Through a global network of 188 National Meteorological and Hydrological Services (NMHSs) of its Members, WMO plays an important role in weather and climate observation and monitoring, understanding of climate processes, the development of clear, precise and user-targeted information and predictions and the provision of sector-specific climate services, including advice, tools and expertise, to meet the needs of adaptation strategies and decision-making.

WMO spearheaded global efforts to monitor the environment and address potential hazards such as global warming, climate change and sea-level rise. WMO co-established with UNEP the Intergovernmental Panel on Climate Change (IPCC) and played a part in paving the way for the adoption of the United Nations Framework Convention on Climate Change (UNFCCC). Through its Global Atmosphere Watch (GAW) programme, WMO plays a crucial role in the monitoring of greenhouse gases.

Both WMO and NMHSs have been involved with the activities of the UNFCCC since its very inception in 1992. WMO, through its World Climate Programme (WCP), World Climate Research Programme (WCRP), Atmospheric Research and Environment Programme (AREP), Global Atmosphere Watch (GAW) monitoring network (greenhouse gases and ozone) and Disaster Risk Reduction (DRR) Programme, assists Members, in particular developing countries, to improve their understanding and assessment of impacts, vulnerability and adaptation and to make informed decisions on practical adaptation actions and measures to respond to climate change on a sound, scientific, technical and socio-economic basis, taking into account current and future climate change and variability.

6.2 WMO Initiative on Climate Change Adaptations (WICCA)

WMO is planning to launch an Initiative on Climate Change Adaptations as a way of addressing some of the challenges of adaptations to climate change. The Mission of this initiative is "To facilitate provision of user oriented climate information, products, advisories and services to support national and regional climate risk assessment, climate adaptation planning and implementation practices for sustainable development".

Objectives of the WICCA are to:

- Facilitate use of climate information for mainstreaming climate risks in decision making;
- Make available data and information for developing adaptation strategies and integrating them in national development agenda;
- Enhance the national capacities in provision of user-oriented climate information;
- Help develop regional capacities; and
- Support the scientific foundation for climate adaptation strategies

Through climate observations and research, the initiative will use climate scenarios, databases and climate predictions to provide climate information for adaptation, sectoral advisory services and climate monitoring. Capacity building will be one of the major components. The major outputs will include provision of climate information, climate outlooks, climate risk assessment and early warnings. Figure 1.13 depicts the components and outputs of the WICCA.

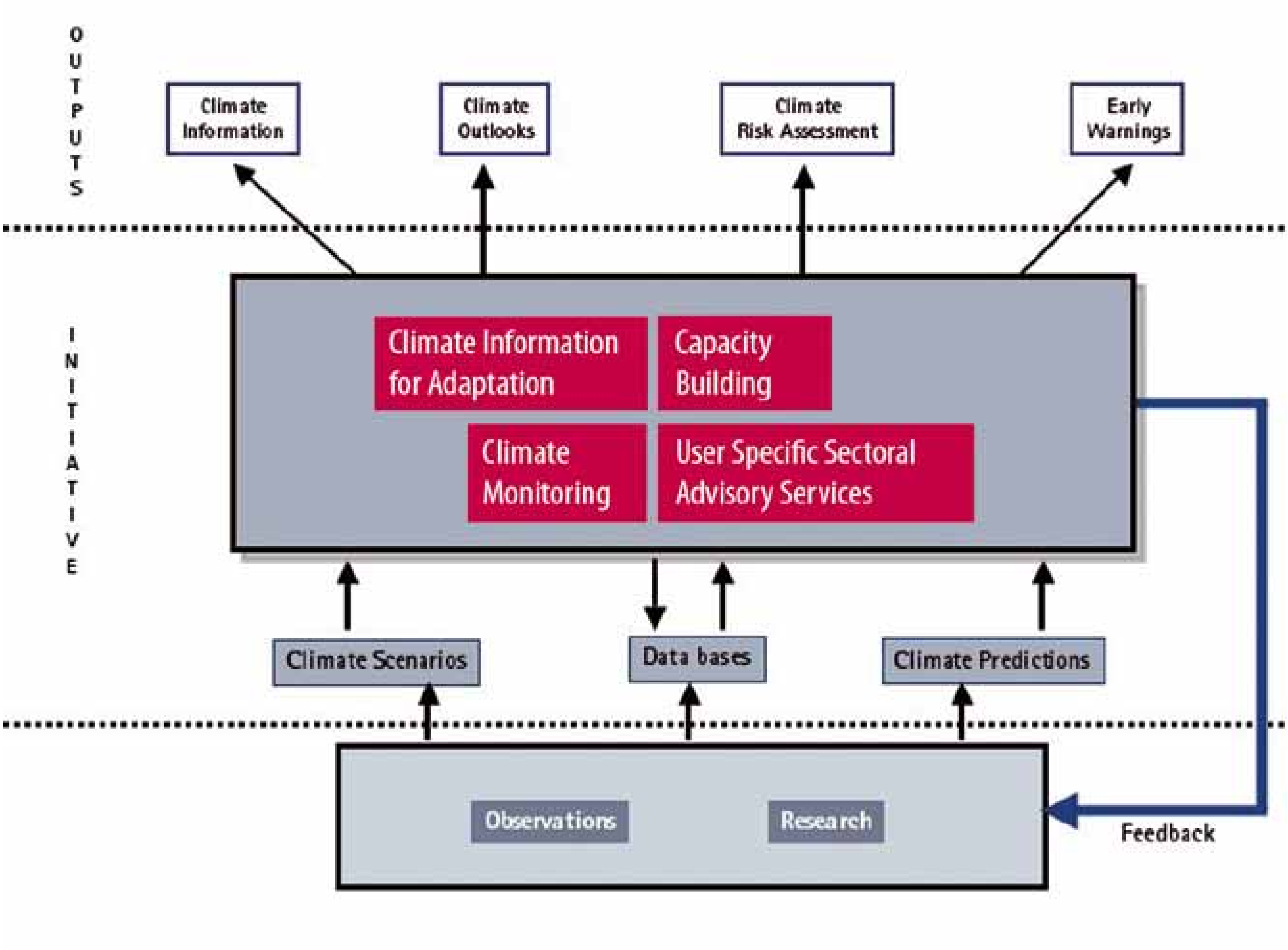


Figure 1.13: Components and outputs of the WICCA

6.3 The World Hydrological Cycle Observing System (WHYCOS)

Adaptation to the impacts of climate change on water resources is dependent on efficient river basin integrated water resources management. However, efficient water resources management and informed decision making is currently hampered by a lack of reliable hydrological information system in many parts of the world, especially in developing countries. In response to this problem, WMO launched in 1993 the World Hydrological Cycle Observing System (WHYCOS) programme, with the aim of improving the basic observation activities, strengthening the international cooperation and promoting free exchange of data in the field of hydrology. The programme is implemented through various components (HYCOSs) at the regional and/or basin scale. Figures 1.14 and 1.15 show the general scheme of a HYCOS data collection and dissemination network.

WHYCOS is a global programme, developed in response to the scarcity or absence of accurate data and information accessible in real or near real time on freshwater resources in many parts of the world, particularly in the developing countries, caused by the deterioration of many observing networks and insufficient data management capabilities. WHYCOS's ultimate objective is to promote and facilitate the collection, analysis, exchange, dissemination and use of water-related information, using modern information technologies. The programme provides the national, regional and international community with basic data for monitoring and managing water resources through observations of the hydrological cycle.

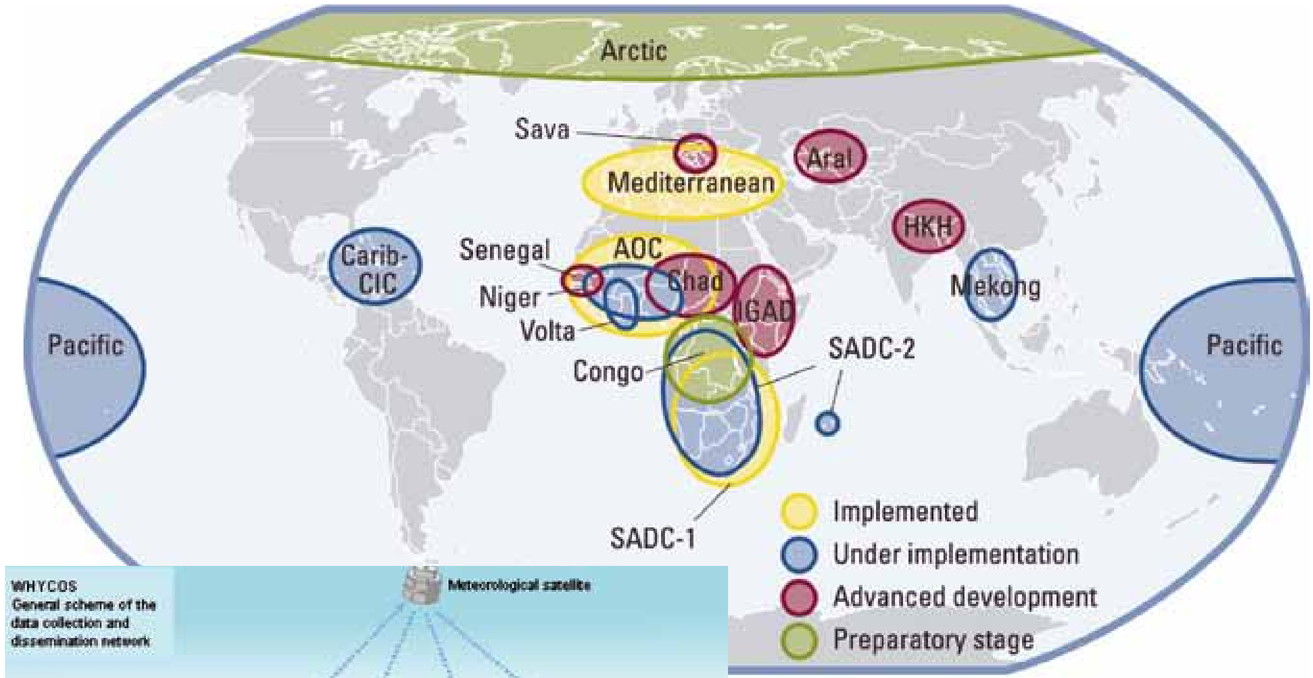


Figure 1.14 (above): Status of Development of the WHYCOS programme

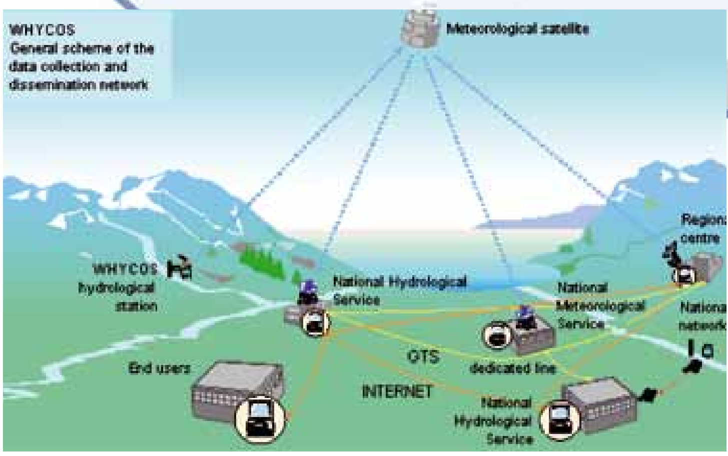


Figure 1.15 (left): General scheme of data collection and dissemination network

6.4 Associated Programme on Flood Management

The Associated Programme on Flood Management (APFM) was launched in August 2001 as a joint initiative of the World Meteorological Organization (WMO) and the Global Water Partnership (GWP). It promotes the concept of Integrated Flood Management (IFM) as a new approach to flood management. The programme has been financially supported by the governments of Japan and the Netherlands. A Technical Support Unit (TSU), embedded in the WMO's Hydrology and Water Resources Branch, acts as its Secretariat.

The mission of the APFM is to „support countries in the integrated management of floods" within the overall framework of Integrated Water Resources Management (IWRM). Regional Pilot Projects have been implemented to test and demonstrate the applicability of IFM principles. These projects are:

South Asia
The pilot project is named „Community Approaches to Flood Management" and is being implemented in selected flood-prone villages in Bangladesh, India and Nepal.

Africa
Two pilot projects have been implemented, drawing up strategies for flood management in the Lake Victoria Basin in Kenya and in the Kafue Basin in Zambia respectively.

Central and Eastern Europe
In collaboration with the GWP Central and Eastern Europe (GWP CEE), a pilot project in Central and Eastern Europe has focused on the preparation of a status of the impacts of- and responses to- various flood events with a focus on flash floods.

South America
The pilot project has been developed and coordinated in Brazil and in Uruguay so as to develop non-structural actions to manage floods within the framework of IFM.

Central America (planned)
A pilot project is planned.

Experiences and lessons learned form the pilot projects will be used to prepare detailed plans for major projects in the regions.

7. Conclusions

Based on the information provided in the preceding chapters, a number of conclusions can be made. Climate poses a big problem and is a threat to sustainable development in many countries, especially developing countries. Africa's vulnerability to climate change is higher than other continents due to a number of factors, which include a lack of appropriate political, technological and institutional framework, dependence on natural resources, low income, lack of sufficient technological capacity, lack of basic information, insufficient monitoring and observation systems and large, structurally important settlements in vulnerable areas. Further, Africa's adaptation capacity to climate change is low due to many problems as indicated above. Sound policies and various measures taken to adapt to climate change as proposed in chapter 5.3 above, can reduce vulnerability and risks associated with climate change impacts. Africa's water resources are already facing serious risks and the situation is likely to deteriorate further in the future. This trend has to be reversed by investing in water resources development infrastructure as a critical opportunity. Transboundary water resources management is essential in Africa. Greater understanding of water resource systems is required. This calls for data and information on water resources. Greater communication is required amongst climatologists, hydrologists and water managers, for better planning and integrated water resources management. Current water management practices need to take better consideration of the effects of climate change.

Bibliography

African Development Bank and others (2002). Poverty and Climate Change: Reducing the Vulnerability of the Poor, a Contribution to the Eight Conference of Parties to the United Nations Framework Convention on Climate Change. Consultation Draft. October 2002.

IPCC, 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK.

IPCC, 2001. Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, in Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Lingen, P.J., Dai, X., Maskell, K. and Johnson, C.A. (eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY, U.S.A.

IPCC, 1996. Climate Change 1995. Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses.

J. I. Matondo, 2008. Climate Change and Variability Impacts on Water Resources in Africa, In Proceedings of the First African Water Week, March 2008.

UNDP, 2008. Human Development Report 2008, "Fighting Climate Change: Human Solidarity in a Divided World".

UNDP, 2004. Adaptation Policy Frameworks for Climate Change. Developing Strategies, Policies and Measures. Annex A. Glossary of Terms.

UNFCCC, 2006. Report on the African Regional Workshop on Adaptation. United Nations Framework Convention on Climate Change. 23 September 2006.

World Meteorological Organization (WMO). Concept paper on the Role of WMO and NMHSs in the Implementation of the Nairobi Work Programme, April 2007.

World Resources Institute, 2007. Climate Analysis Indicators Tool (CAIT) Version 4.0. Washington, DC.

Chapter 2

Integrated Water Resources Management as a Medium for Adapting to Climate Change

Conceptual, scaling, impacts modelling and adaptation issues within a southern african context

By Roland E. Schulze. School of Bioresources Engineering & Environmental Hydrology. University of KwaZulu-Natal. Pietermaritzburg, South Africa

Contents

1. Introduction

One of the plethora of definitions of Integrated Water Resource Management (IWRM) which abound in the literature is that

IWRM is a philosophy, a process and a management strategy to achieve sustainable use of resources by all stakeholders at catchment, regional, national and international levels, while maintaining the characteristics and integrity of water resources at the catchment scale within agreed limits (DWAF, 1998).

If this South African definition is adopted in this paper, then it may be argued both implicitly and explicitly that IWRM should be a sound medium by which to effect adaptation strategies to impacts of an uncertain future on the water sector under conditions of climate change, and this across a range of spatial and temporal scales.

This paper therefore sets out to discuss issues of getting to grips with some realities and practicalities of IWRM in a context of southern Africa and of climate change (CC) by first asking who water managers are and what they manage, in light of some major paradigm shifts which have taken place in water resource management since the early 1990s. Thereafter, differences in IWRM which exist between more developed and lesser developed countries are highlighted, followed by brief explanations on how the interrelationships between climate change and the hydrological cycle operate, and why the hydrological cycle tends to amplify changes in climate. These sections are followed by one on scale issues and the challenges these present in climate change studies, including some general statements on scales at which operational decisions are made in the water sector, on complexities of spatial and of temporal scales in adapting to climate change within a framework of IWRM and how the spatial scale dilemma in climate change studies has been addressed in South Africa to harmonise with other modelling initiatives in IWRM. Simulation modelling is the primary tool used to assess impacts of CC on hydrological responses, therefore, the next section, on impacts modeling, is prefaced by enquiring into the significance of the water sector in CC studies, followed by a discussion on model requirements for effective climate change impact studies and why the ACRU system is used as the preferred hydrological simulation model in southern African CC impacts studies. The final major section of the paper relates to selected issues on adaptation to CC in the water sector, with emphasis on experiences in South Africa. Adaptation is first placed within a policy framework, both at an overarching national level and then more specifically within the water sector. Among the challenges facing adaptation to CC are, on the one hand, the many uncertainties which remain and on the other, putting into practice the many excellent thoughts which have already emanated from the water sector itself in regard to IWRM, including the role of groundwater, design hydrology, policy/legislation, monitoring and the inter-linkages with the agricultural sector. A framework for adaptation to CC is presented for South Africa, but limits to adaptation are also highlighted. The paper concludes by emphasising that barriers to IWRM, particularly those more frequently evident in developing countries, should not become barriers to climate change adaptation in those countries.

2. Getting to grips with the realities and practicalities of IWRM within the context of climate change

In regard to some realities and practicalities of IWRM within the wider contexts of southern Africa (and Africa as a whole) and of climate change, three issues are addressed, viz. who water managers are, what paradigm shifts they have had to contend with over the past two decades and what differences exist in managing water resources between lesser developed and developed countries.

2.1 Who are water managers and what do they manage?

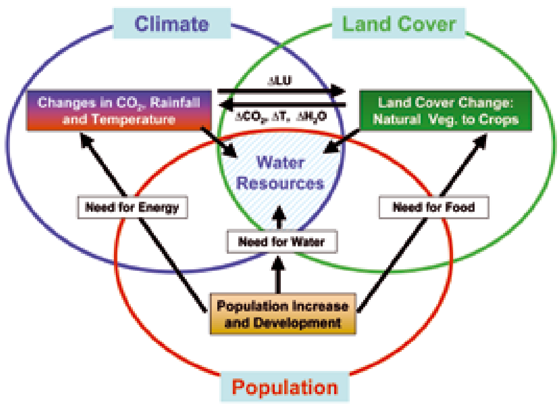


Figure 2.1: The climate - land cover - water resources cycle Schulze, 2007; Idea: Harding & Kabat, 2007

For the professional water resources manager the management of water involves the regulation, control, allocation, distribution and efficient use of existing supplies of water under present and future conditions. This includes management responsibilities towards off-stream users such as irrigators, thermal power plant operators (cooling), municipalities and the industrial sector, as well as towards the development of new water supplies, the control of floods and the provision of water for in-stream uses such as navigation, hydro-electric power, recreation and environmental flows (Figure 2.1).

From a non-professional water management perspective, all levels of government, as well as the private sector and individual stakeholders are routinely engaged in the management of water, be it directly or indirectly. Hence, technically, every individual who uses water is in a manner of speaking a water manager, from the water resource professional to the woman in the village who draws water from a spring or river. Water managers certainly include agriculturalists, both the large-scale commercial farmers who use mostly technical water related systems, and the small-scale subsistence farmers with their rainfed agriculture. Addressing the adaptation options which farmers in the lesser developed countries have is particularly critical, owing to the direct impacts climate variability and change could have on their livelihoods. Nevertheless, water managers are typically considered to be people who are formally trained and involved in some institutionally organised component of water development, delivery/regulation, and who have responsibility and accountability for the decisions that are made (Appleton et al., 2003).

Water managers have to deal with a host of interlinked and integrated issues (Figure 2.2), not only in regard to supply, quality and distribution of water, but also with resource vulnerability and reliability, sustainable water use, biological diversity, ecological integrity with respect to water under both present and future conditions and, in Africa, with issues of equity of water allocation and the Millennium Development Goals.

For many water managers in developing countries, vulnerability to future climate changes may seem to be a far-distant problem. Certainly many would argue for focusing on currently more pressing issues related to population growth, economic underdevelopment, HIV/AIDS and lack of investment in water infrastructure, rather than on climate change. To some water managers, dealing with natural climate variability and climate-related hazards such as droughts and floods has always been a part of their routine concerns. For them, taking into account climate change does not necessarily imply adding any new "magic strategies" to their present practices for coping with climate extremes. What they do have to recognise, however, is that climate variability may be increasing and that future weather for many regions is projected to be more extreme more frequently.

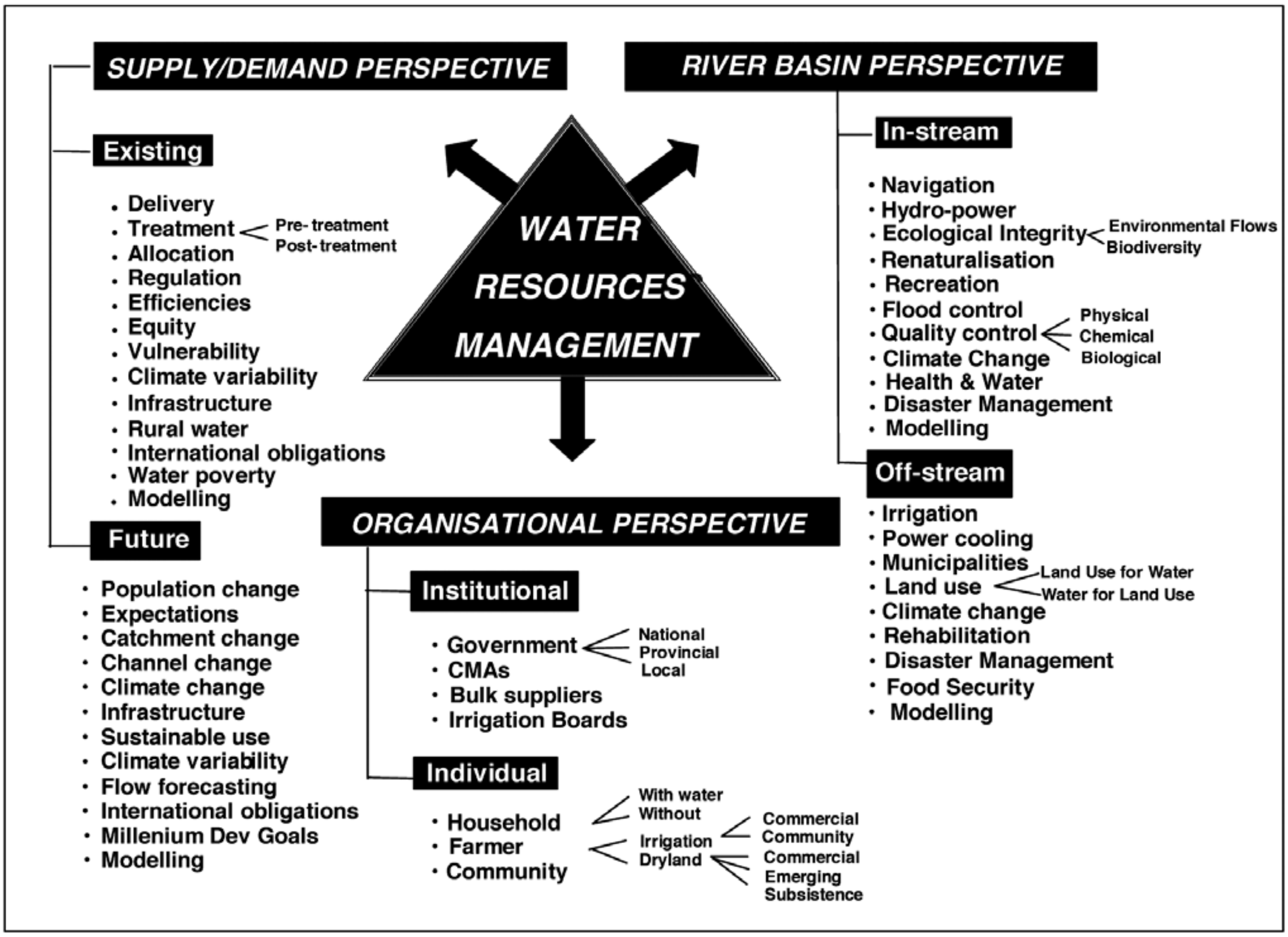


Figure 2.2: The interlinked nature of water resources management (Schulze, 2005a)

2.2 Major paradigm shifts have taken place in water resource management since the early 1990s

Adding to the many challenges which water managers face is the fact that the past decade or two has seen a number of paradigm shifts in water resources management which are likely to intensify in the future; in some measure also as a manifestation of climate change.

Some of the paradigm shifts, according to Schulze (2005b), place a greater emphasis than was the case in the past on

- environmental issues (vs. only functional engineering systems)
- sustaining the resource of water (vs. only harnessing it)
- conflict management in water (vs. problem solving)
- assessing the value of water (vs. to only the volume of water)
- forecasting hydrological responses (vs predicting extremes)
- addressing water quality issues (vs. only those on water quantity) and
- whole, and holistic, catchment management (vs. focusing only on channel and reservoir control).

2.3 Differences in characteristics influencing IWRM exist between more developed and lesser developed countries

To this day large tracts of Africa remain underdeveloped. Fundamental differences in infrastructure and capacity, as well as in economic and socio-political characteristics may be identified between more developed countries (DCs) and lesser developed ones (LDCs) which have a strong bearing on IWRM and the manner in which impacts of CC need to be contextualised in the water sector. These differences are summarized in Table 2.1.

More developed countries	Lesser developed countries
Infrastructure • High level of development; infrastructure generally improving • Infrastructure decreases vulnerability to natural disasters • High ethos of infrastructure maintenance • High quality data and information; well coordinated	**Infrastructure** • Often fragile; frequently in a state of retrogression • High vulnerability to natural disasters • Low ethos of infrastructure maintenance • Data and information bases not always available
Capacity • Abundant scientific and administration skills available • Expertise developed to local levels • Flexibility to adapt to technological advances	**Capacity** • Limited scientific and administration skills available • Expertise highly centralised • Often in survival mode; technological advances may pass-by
Economy • Mixed, service driven; buffered by diversity • Economically independent and sustainable • Long term planning perspective • Wealthy; money available for IWRM and climate change adaptation	**Economy** • High dependence on land; vulnerable to climate • High dependence on donor aid, NGOs • Shorter term planning perspective • Limited wealth; less scope for IWRM and climate change adaptation
Socio-Political • Low population growth • Generally well informed public; high appreciation for science • High political empowerment of stakeholders • Decentralised decision making	**Socio-Political** • High population growth; pressure on land • Generally poorly informed public; less appreciation for science • Stakeholders often not empowered; afraid to exert pressure • More centralised decision making
Environmental Awareness and Management • High level of expectation in planning and IWRM • Desire for aesthetic conservation	**Environmental Awareness and Management** • Lower level of expectation and attainment of goals • Need for basics for living

Table 2.1: Characteristics influencing IWRM, and hence responses to climate change, in more developed vs. lesser developed countries (after Schulze, 1999)

Because of the high levels of expectation of IWRM in developed countries, as well as a pro-active perspective and a generally non-life-threatening environment and infrastructure, IWRM in developed countries can focus more on long-term issues, on quality of life and on the environment, including (Schulze, 1999) preservation of the environment (with a focus on aquatic ecosystems), the re-naturalisation and rehabilitation of the catchment and its receiving streams, matters pertaining to non-point source pollution, demand management of water and potential impacts of climate change on water resources, with attendant adaptation strategies.

As a consequence of poorer infrastructure in LDCs, higher vulnerability to natural events and often being in survival mode, IWRM in LDCs frequently has to address more immediate issues (Schulze, 1999) such as:

- creating basic water supplies (vs. supplying water of the highest quality in the DCs)
- managing the water supply (vs. demand management)
- poverty alleviation (vs. quality of life enhancement)
- harnessing the environment (vs. sustaining it)
- short term needs (vs. long term perspectives)
- climate variability, both intra- and inter-seasonal (vs. climate change)
- creating an infrastructure (vs. maintaining, improving it).

With the tendency for issues on IWRM to emanate largely from DCs, it is necessary to focus on problems of IWRM, such as those above, which are likely to have strong bearing on adaptation strategies to CC in LDCs.

3. How does climate change link with the hydrological system?

In its simplest form, the natural hydrological system may be represented by

$$Q = P - E +/- dS$$

where Q equals streamflow, P is precipitation, E represents evaporation, made up of transpiration (E_t), evaporation from the soil surface (E_s) and free water evaporation (E_w) from intercepted water and that from open water surfaces (lakes, dams, river channels), and dS constitutes the changes in storage of soil and groundwater. With CC the primary forcing function, viz. a change (d) in CO2, alters E_t in the hydrological equation directly through a reduction in transpiration, while the secondary forcing function, i.e. the resultant change in temperature (dT), enhances both E_s and E_w and simultaneously, through changes in atmospheric pressure belts, alters precipitation patterns and attributes and, consequently, dS (Schulze, 1997).

By itself, increased atmospheric CO2 concentrations (Fig. 2.3) can have significant hydrological repercussions through reductions in stomatal conductance of plants, thereby reducing maximum and thus actual transpiration rates, with the reductions varying between C3 and C4 plants, as well as the plants' biomass and the level of soil moisture content (Schulze, 1995; 2003).

Temperature changes, by themselves, will have direct and indirect bearing on water resources through changes (Schulze, 2003), for example, in

- potential evaporation from dams or as an increased atmospheric demand on the soil/vegetation complex, and hence
- soil moisture, and consequently vegetation/crop water use and the potential to generate runoff and, therefore, changes in
- total ("actual") evaporation from the soil/vegetation complex and hence partitioning of rainfall into evaporation and runoff components,
- irrigation practices, with different crop water demands, yield increments per mm irrigation and water use efficiencies, as well as enforced changes to modes of scheduling, all of which are likely to be exacerbated by increased
- heat wave episodes and associated
- droughts, in regard to their frequencies, severities, durations and spatial extents.

At different scales of space and time, any changes in the magnitude of rainfall, its intensity, duration, seasonality and persistence of wet/dry rainfall sequences will all affect the partitioning of rainfall into its different runoff generating components, and hence river flows and groundwater recharge.

These changes (Schulze, 2003) may be grouped into

- changes in global scale circulation patterns such as those which result in El Nino-Southern Oscillation events with their associated droughts and floods, and furthermore with possible (but not yet confirmed) increases in, and southward movement of, tropical cyclone activity around southern Africa;
- changes in magnitudes of annual rainfalls, and their seasonal distributions, with repercussions in water demand and supply patterns, reservoir sizing and operations or environmental flow requirements;
- changes in individual event characteristics, such as increases in convectivity, which could result in shorter hydrographs with higher peak discharges and higher resultant sediment yields;
- changes in the number of raindays, which would affect runoff generation, irrigation water demand and recharge to groundwater;
- changes in extreme events, including the possibility of simultaneously more flood events and droughts over a period of time, which would alter reservoir sizing and possible changes in hydrological design (e.g. spillways) and disaster management preparation.

It should be stressed first, that these individual effects brought about by changes in greenhouse gas concentrations, temperature and rainfall will act in combination with one another, thereby either partially reinforcing or self-cancelling any hydrological impacts and, secondly, that the impacts of the individual drivers will not be spatially uniform within a region, with certain areas being more vulnerable than others to changes in hydrological responses (Schulze and Perks, 2000).

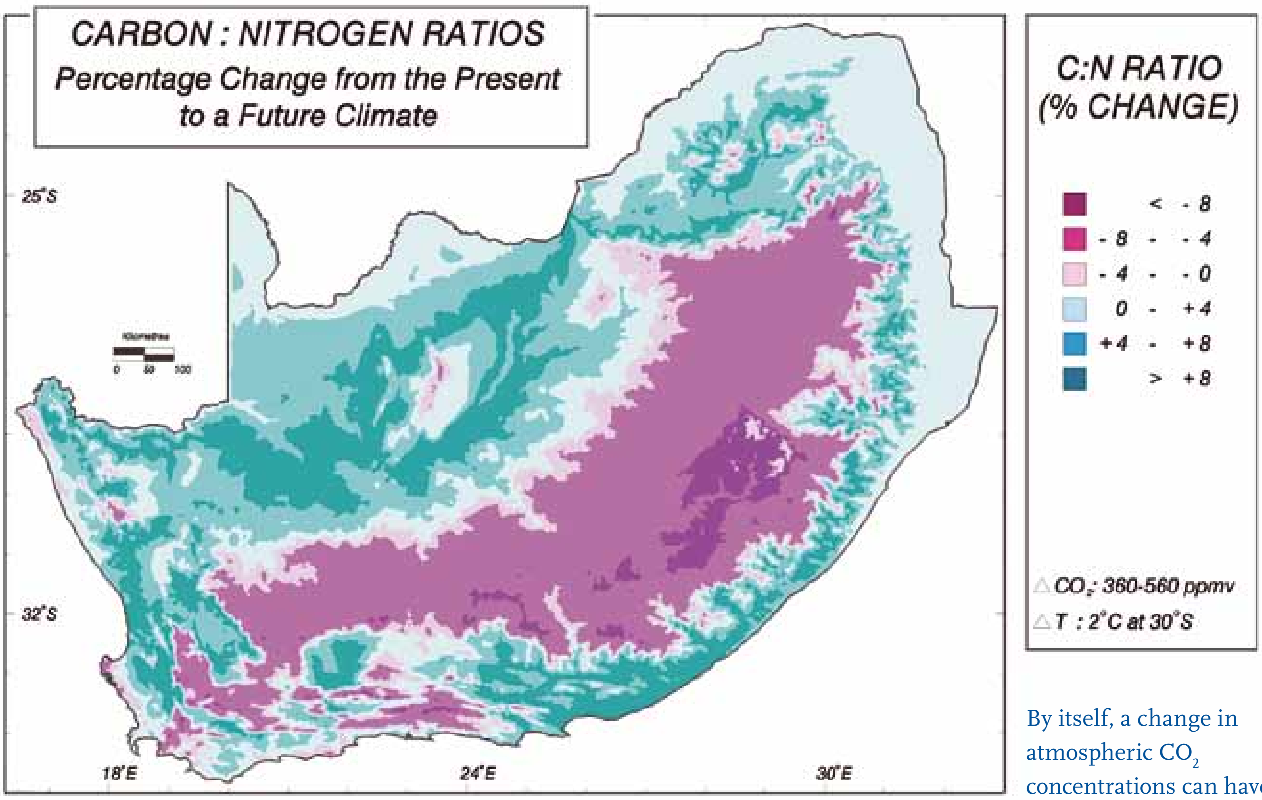


Figure 2.3: Carbon: Nitrogen Ratios

By itself, a change in atmospheric CO_2 concentrations can have important hydrological repercussions.

4. Why does the hydrological cycle amplify changes in climate?

Probably the most common statement made about climate change in relation to the water sector is that the hydrological cycle amplifies, or intensifies, in particular any changes in rainfall characteristics. Of the six causative factors of the amplification phenomenon identified in the literature (e.g. Bugmann, 1997; Schulze, 2000), two are highlighted in the context of climate change.

First, **Hydrological Responses Occur Non-Linearly**, with clear distinctions in responses needing to be made between processes occurring episodically (e.g. rainfall), vs. cyclically (e.g. evaporation), ephemerally (e.g. lateral flows) or more or less continually (e.g. flows from the groundwater store). Additionally, certain responses are rapid (e.g. surface runoff), while others occur at the time scales of days (e.g. lateral flows) or months (e.g. groundwater movement). These different rates of process responses introduce a high degree of non-linearity to the system, and this non-linearity is exacerbated when the natural system is replaced by anthropogenic systems which introduce land use changes or reservoirs, or when climate drivers change.

Secondly, **Runoff Responses Require Thresholds to Occur**, with surface runoff generation, for example, involving two distinct processes each with a different threshold in order to occur. On the one hand, overland flow on high ground occurs when rainfall intensity exceeds the infiltration rate into the soil, while saturated overland flow requires a minimum upslope area over which lateral flows can accumulate and move downslope to saturate the area around the channel, with any rain then falling on the saturated zone of varying extent over time, then being converted to overland flow. In both cases a threshold of rainfall needs to have occurred to trigger a response. Similarly, subsurface flow generation is determined by two distinct thresholds which need to be exceeded, with the threshold for interflow (i.e. subsurface lateral flow down a hillslope) to occur depending, inter alia, on soil horizonation, different hydraulic conductivities along a hillslope toposequence as well as on slope shape (e.g. concave, convex), while the threshold for baseflow to occur is determined, inter alia, by aquifer properties, the amount of recharge to groundwater that has taken place and whether or not the groundwater level is "connected" or "disconnected" to the channel. The threshold for the generated runoff to flow down a natural channel will be subjected to hydraulic laws which are determined, inter alia, by channel length, shape, roughness and slope. However, these thresholds would be modified markedly by human interventions through dam construction, canalisation or water transfers into or out of the system. In all the above examples, thresholds need to be exceeded for hydrological responses to be triggered, but once they have been exceeded, the responses often proceed at an accelerating rate with changes in rainfall.

5. Scale issues and challenges in integrating climate change studies with water resource management

Scale issues in climate change studies usually focus on problems associated with downscaling from Global Climate Models to more appropriate local scales applicable to hydrological modelling. This discussion will, however, highlight some more generic questions related to scale by

- first making some general observations on decision taking at the "scales that count",
- thereafter, addressing some considerations of spatial scales when adapting to climate change within a context of IWRM,
- followed by a parallel discussion, but on temporal scales and, finally
- outlining the manner in which hydrologically homogeneous response zones, termed Quinary Catchments, have been delineated in South Africa for climate change impact studies.

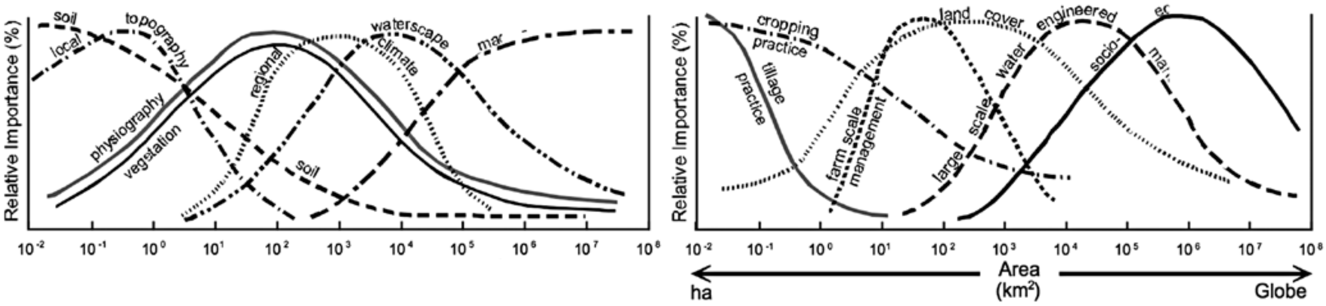


Figure 2.4: Natural heterogeneities (top) and anthropogenic influences (bottom) occur across a range of spatial scales, but dominate hydrological responses over a narrower spectrum (Meybeck et al., 2004)

5.1 Making decisions at the scales that count: some general observations

Hydrological processes and responses on a catchment are complex and take place across a range of spatial and temporal scales, as do those land use practices and socio-economic processes which impact on water resources. All of these will be affected by the magnitude, direction and rate of climate change.

However, within this complex hydrological landscape, different natural and anthropogenic influences dominate hydrological system responses depending on the scale involved.

This is illustrated in Figure 2.4 (top) for the natural hydrological system (Meybeck et al., 2004; Schulze, 2004) through the greater dominance of

- soil properties and local topography (slope, aspect, altitude), which are relatively invariant (i.e. non-changing over time), as major hydrological response agents at small catchment scale (~ < 101 km2), vs
- physiography (i.e. the macro-landscape) and, in phase with that, the more variant (i.e. changing over both space and time) broad vegetation units, as well as regional climate (e.g. precipitation, temperature and evaporation patterns), the waterscape (e.g. channels, floodplains, wetlands, lakes and estuaries with their associated ecosystems) and macro-climate (synoptic scale events), all of which are dominant influences on hydrological responses at the larger catchment scales of ~ 101 to 105 km2 and which are affected by CC.

Similarly, anthropogenic influences on the hydrological system are also scale dependent (Figure 2, bottom; Meybeck et al., 2004; Schulze, 2004) with, for example:

- tillage practices, cropping practices and farm scale management, all of which will be affected by CC, having major impacts at local hydrological scales, but hardly (or much less so) at larger catchment scales, whereas
- land use and cover as well as water engineering systems (e.g. reservoirs, irrigation, inter-basin transfers) and the status of socio-economic development (e.g. LDCs vs DCs), may all be impacted upon by CC and, by themselves or in combination, may change natural hydrological regimes (Meybeck et al., 2004).

The scale at which adaptation to CC within a framework of IWRM should take place is therefore not one that is easy to answer. As a general observation, however, the appropriate temporal and spatial scales of operation of adaptation within IWRM are those scales at which the policy makers, catchment managers and stakeholders believe that they can achieve their set(s) of objectives for future sustainable resource use. These scales will be defined, inter alia, by

- how effectively an area can be managed,
- what level of development had previously been attained in the area,
- the uniformity of the catchment in relation to biophysical resources (e.g. water, agriculture), human resources, wealth and ease of communication with stakeholders, all of which are influenced by constraints of politics, finances and levels of bureaucracy (Schulze, 1999; 2004).

Within an overarching 'scale of operation' any IWRM plan which includes CC adaptation options will, therefore, have to contain a hierarchy of intermediate and internal smaller space and shorter time scales, in order to define interim stages of implementation, goals or milestones (Schulze, 1999; 2004).

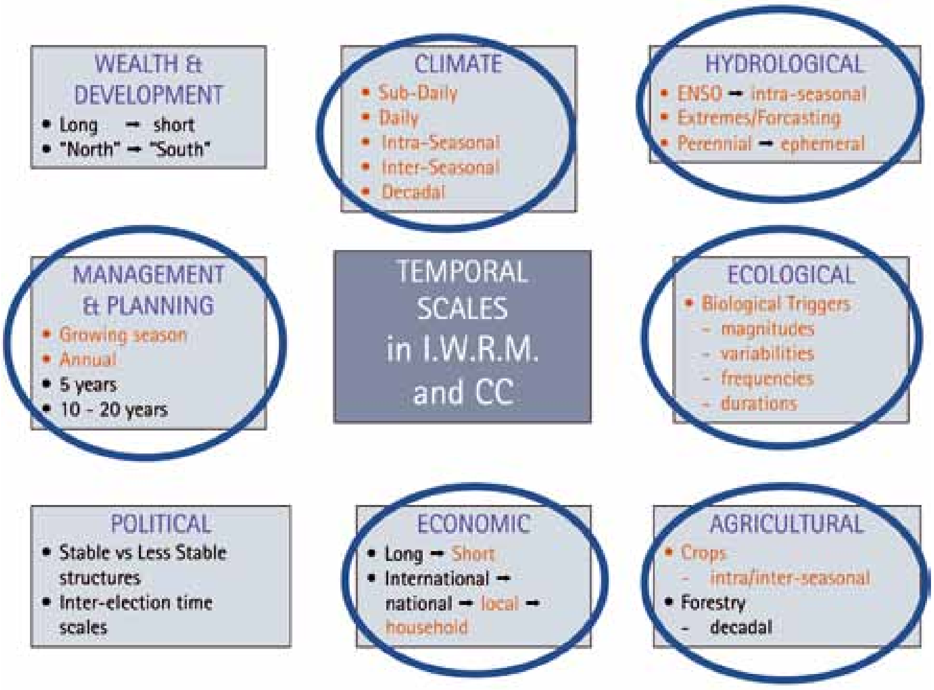


Figure 2.5: Temporal scales in Integrated water resources mangement (IWRM) and climate change (CC)

5.2 Considerations of spatial scales when adapting to climate change within a framework of IWRM

In considering CC, IWRM has to take consideration of all, or some, of the following spatial scales (fig. 2.5):

- global scale, e.g. issues related to water conventions or El Niño-Southern Oscillation (ENSO) scale events
- international scales, e.g. in regard to problems of inter- and/or transboundary rivers
- the national scale, e.g. national water management strategies or agendas
- catchment scales, with each catchment having its own unique water issues
- local government scales with their local, often administrative, initiatives or governance problems
- community scales, at which water availability and ease of access to water may be major issues and
- household scales which, especially in LDCs, may include problems of household water and food security.

Spatial scale issues in the water sector often reflect the overall level of economic development, e.g. in poorer countries or regions within a country, the space scale tends to be much smaller, determined by factors such as the distance range at which one can mobilise communities, or the availability of land around a village, or access to local water sources (Schulze, 1999).
In a rural African context, Frost's (2001) observations on IWRM also hold true for adaptation strategies for CC in that the larger the spatial scale, the more difficult management, and hence adaptation, becomes with respect to

- the range of local resources available and
- the number and diversity of stakeholders who have the necessary skills, interests, resource endowments, as well as capacities for management. This implies that agreement/consensus is not easy, and plans of action become more complex and time-consuming.

When putting adaptation strategies into practice "on the ground", Frost's other observations equally hold true in that when focussing at too broad a scale, it is often impossible to keep in perspective the 'fine-grained variation' embodied in all the various adaptation procedures and one runs the risk of overlooking local features, local needs, local circumstances and/or local aspirations, especially of the poor within the catchment, while on the other hand, when focussing on too fine a scale, there is a danger of losing sight of the wider context of adaptation strategies and thus losing sight of the overall governing processes of IWRM (Frost, 2001).

One often overlooked spatial scale consideration related to CC is that not only are shifts in climate and associated land uses going to take place geographically by latitude and longitude, but that migration of temperature and precipitation patterns in mountainous areas will also be altitudinal, and that there will potentialy be changes with in land use with altitude as well as in the form of precipitation (snow vs rain) and its intensity.

5.3 Considerations of temporal scales when adapting to climate change within a framework of IWRM

From the above discussion it becomes evident that, just as with spatial scales, time scales in IWRM should not be viewed as static when consideration is given to CC adaptation options. Rather, temporal scales should be perceived as a hierarchy of overlapping scales (Schulze, 1999) juxtaposed within one another.

These include

- climate scales, not only at the decadal time frame of the climate change phenomenon per se, but also at the scales at which they will manifest themselves in day-to-day life at inter-seasonal, intra-seasonal and daily time scales, because climate at these various scales 'drives'
- river flow scales, which for communities dependent on surface water will range from the irregular but recurring high flow and drought sequences related to the ENSO 'cycles' at multiple year scales, and the inter-seasonal variability of flows associated with such; or the seasonality and concentration of streamflows within a year at a given location; to intra-annual flow variability; or the forecastability of river flows with lead times from days up to a season ahead; or to the recurrence intervals of floods or droughts of a specific magnitude; while for communities dependent on groundwater the temporal recharge patterns and water table fluctuation are of importance;
- aquatic ecosystems time scales, which are dependent on magnitudes, frequencies and durations of low flows and high flows as biological triggers, or by the number of biologically significant positive hydrograph reversals in a river, all of which are projected to alter with CC;
- agricultural time scales, in which the CC:IWRM interrelationship the dynamics of the interdependence of crops on water (in the soil and from the river) and water (in rivers and the soil) on crops becomes an important (albeit complex) one;
- economic time scales, ranging from longer term internationally significant phases of growth vs. recession, to the way these play out at national level, to regional or local to shorter term time scales that affect the individual rural subsistence household;
- political time scales, in which a distinction needs to be made between essentially stable government structures, in which CC adaptation strategies are more easily effected than under potentially unstable government structures; and also inter-election time scales for national and local government structures, during which promises of water reform and adaptation plans may be made;
- management and planning time scales, often of the order of 10-20 years and into which planned adaptation has to slot; and
- wealth/development level time scales, where wealthy countries tend to have longer term planning horizons which can accommodate CC adaptation strategies more readily than poorer countries, which tend to have shorter planning horizons (Schulze, 1999; 2004).

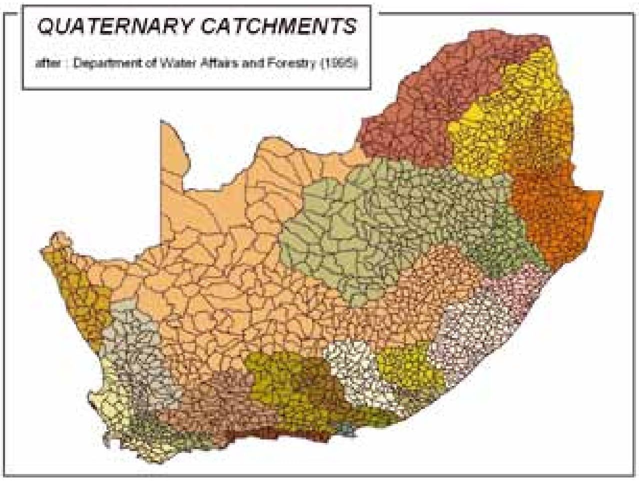
In summary, it needs re-emphasising that the time scales at which CC adaptation strategies within a framework of IWRM are best initiated and effected are related to the scales at which people on the ground are both being impacted upon by the availability of land and water resources, and are impacting upon these resources.

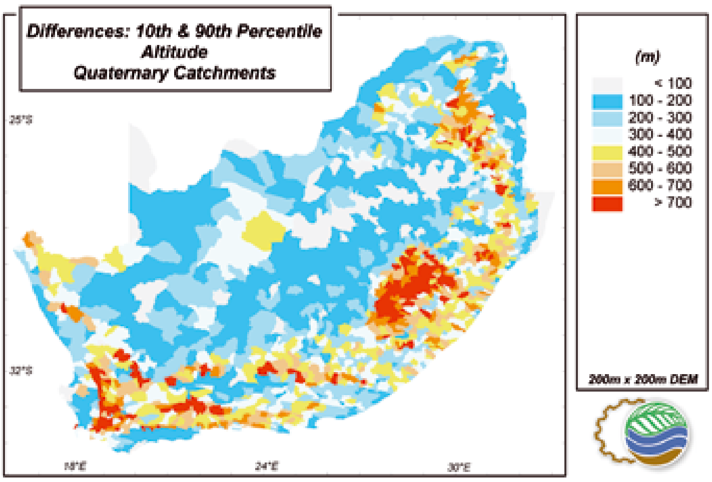
5.4 Delineating hydrologically homogeneous response zones for climate change impact studies: the concept of the quinary catchment

An appropriate spatial scale which is relevant to practical, day-to-day adaptation decisions in regard to CC is one from which hydrological and associated agricultural responses are considered homogeneous. But, what is an appropriate spatial scale? In southern Africa, for example, the contiguous area of ~1.267 million km2 comprising South Africa, Lesotho and Swaziland has been delineated in 22 Primary Catchments (fig 2.6), each of which has been sub-delineated into smaller Secondary, even smaller Tertiary and finally into 1,946 fourth level Quaternary Catchments (QCs). Until very recently these QCs had been regarded as homogeneous enough for operation analyses and day-to-day decision making. However, over half of these QCs have been defined as still being too heterogeneous hydrologically for effective water management (Schulze and Horan, 2008), particularly in their responses to perturbations in climate.

Therefore, a 5th level of Quinary Catchment has now been delineated by sub-dividing the 4th level QCs into hydrologically and agriculturally more homogeneous spatial units with respect to rainfall, evaporation, soils and slopes (Schulze and Horan, 2008). Each QC was sub-delineated into 3 Quinaries of unequal size using Jenks' optimisation procedures based on natural breaks in altitude. Altitude was used as the criterion for sub-delineation as it is a strong determinant of rainfall, temperature (and thus evapotranspiration) and slope gradients which together exert strong influences on soil properties and land use, and hence on stormflow and baseflow generation, peak discharge and sediment yield. Consequently RSA, Lesotho and Swaziland are now divided into 5,838 Quinary Catchments (Schulze and Horan, 2008). For water resources and CC impact studies, each of the Quinaries has been populated with 50 years (1950-1999) of historical daily climate data, as well as with daily climate data downscaled from numerous GCMs from the 2007 IPCC Fourth Assessment Report for present, intermediate future (2046-65) and more distant future (2081-2100) climate projections, and with hydrological soils attributes, land cover attributes and slope gradients.

It is only at such a local scale, at which homogeneous responses to climate change are likely to occur, that it is believed that meaningful adaptation strategies can be developed and implemented. Projected hydrological responses, however, will need to be simulated and in thefollowing section hydrological model requirements for effective climate change impacts studies are discussed and evaluated.





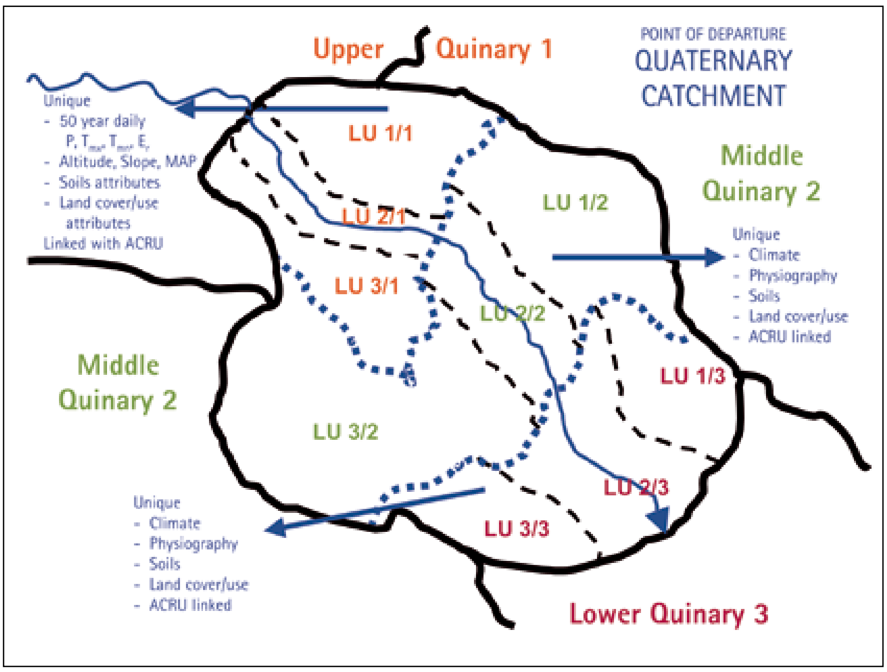


Figure 2.6: Point of Departure Quaternary Catchments

6. On issues of modelling impacts of climate change on the hydrological system

6.1 The Significance of the Water Sector in Climate Change Studies

The superpositioning of a potential “speeding up” of the hydrological cycle through climate change in an era in which water management is already in a state of flux does not simplify matters for the water practitioner; particularly if one bears in mind the amplification effects of changes in rainfall attributes on runoff responses and the vital links that water has to other major natural cycles (e.g. the nitrogen and carbon cycles) and sectors (e.g. agriculture, transport, health or risk management). Appropriate hydrological models will become an increasingly important tool in addressing the consequences of many of these paradigm shifts. A logical question raised is “What is required of a suitable simulation model for effectively assessing impacts of climate change on the hydrological system?” (Schulze, 2005b)

6.2 Model Requirements for Effective Climate Change Impact Studies

a. What Constitutes the Hydrological System Under Investigation?

Modelling impacts of climate change in hydrology involves three “streams” of action which need to be merged (Schulze, 2005b). These are illustrated in Figure 2.7. Climate change demands an innovative approach to modelling hydrological processes, because perturbations in the drivers of these processes (e.g. dP, dT and dCO2 and its feedbacks on transpiration) will result in changes in evaporative demand, in partitioning of rainfall into the different runoff components (i.e. stormflow, baseflow) and, hence, in water quality. In essence these response changes occur on the landscape component of the catchment; on which natural land cover and soils properties may already have been altered by human actions. Key climate

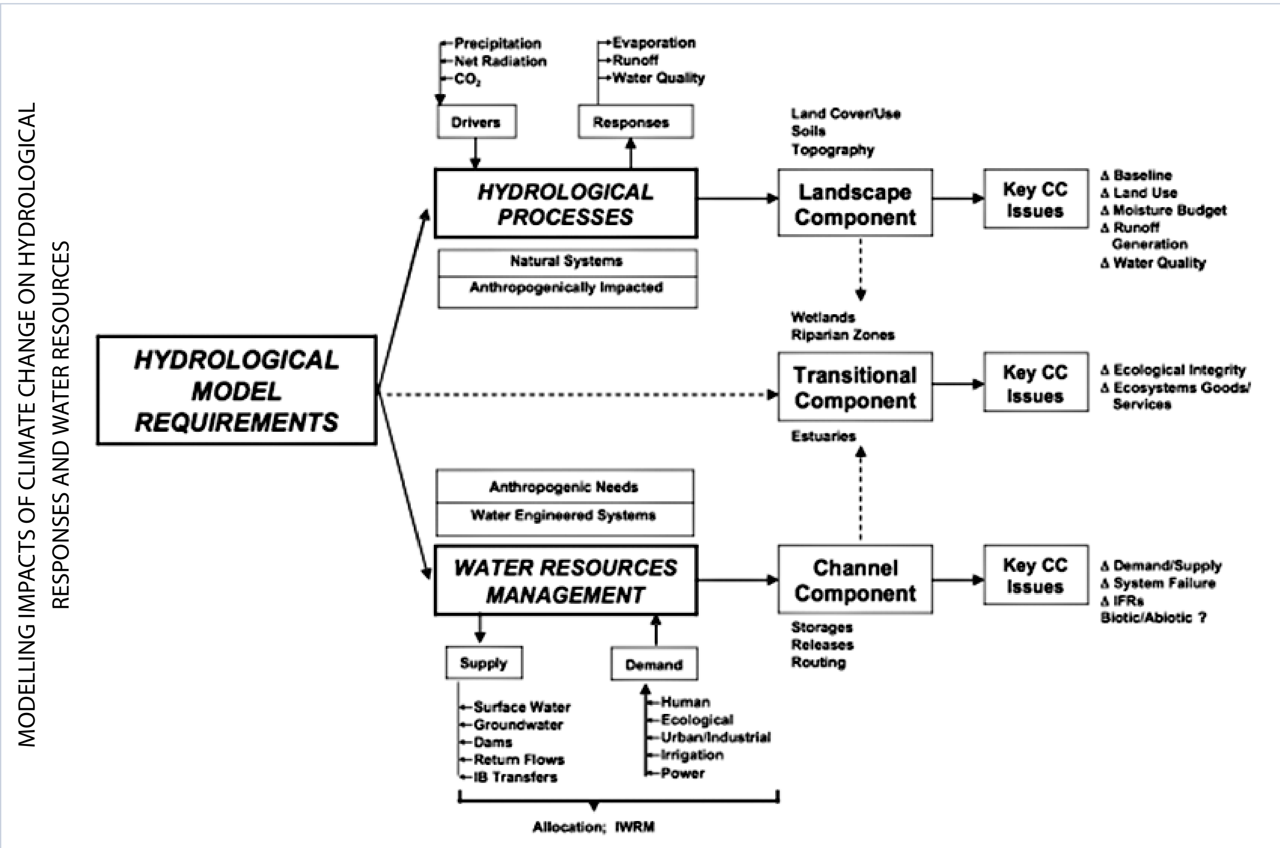


Figure 2.7: Hydrological model requirements under conditions of climate change (Schulze, 2005b)

change issues in regard to the landscape component include alterations to the hydrological baseline against which any further impacts are to be assessed, as well as spatial changes in land use patterns and, hence, in runoff/water quality responses (Schulze, 2005b).

Aditionally, water resources practitioners and managers have to grapple with balancing supply of water (be it from rivers, groundwater, impoundments, return flows or water transfers) with demand for water (e.g. from basic human and ecological needs to requirements for the urban/industry sectors, power generation and irrigation), and to allocate available water in a sustainable manner through holistic planning, i.e. IWRM. In most instances this involves manipulations of the channel component of the catchment through "controls" of storage, releases and routing of water. Key climate change related challenges generally revolve around engineering issues such as changes in the supply of and demand for water; changes to design criteria of hydraulic structures (e.g. dam spillways, stormwater drains) in regard to potential system failure; environmental consequences of changes in natural flow regimes through dam construction or inter-basin transfers, including changes to flow requirements for aquatic habitats and other abiotic/biotic effects downstream (Schulze, 2005b).

Wedged, in a manner of speaking, between the landscape and the channel are the transitional components of the hydrological system, such as wetlands, riparian zones and estuaries. These components are frequently in delicate equilibria, which may "flip" as a consequence of landscape and channel manipulations. Under conditions of global warming these elements may become even more fragile and/or sensitive, and key challenges will be to assess changes in ecosystem goods and services (Schulze, 2005b).

For pro-active water resource management into a future with changed climates, all the above challenges have to be met explicitly or implicitly by appropriate modelling. Hydrological models therefore have to meet certain requirements in regard to process representations and model structure and some of these are identified and discussed below.

b. What Requirements Does this Place on Process Representations and Structure in Hydrological Models?

i. The Need to be Able to Model Explicitly the Dynamics of Different Streamflow Generation Mechanisms

"Streamflow is not simply streamflow"; its different components are generated by different mechanisms, have different hydrological functions and are generated from different (and dynamic) source areas within a catchment, and all of these factors likely to alter with climate change. For example (Schulze, 2005b),

- overland flows, which may be generated either from connected (adjunct) impervious areas, from saturated zones of variable areas or when rainfall intensities exceed infiltrability; have short residence times of minutes to hours; are event-based; remove/transport sediments and other surface material (e.g. fertilizers, pesticides, industrial pollutants) and are critical in peak discharge estimation as well as in water quality determination
- subsurface stormflows have slower response times and different water chemistries
- baseflows, which are sustained by recharge from preferential zones within a catchment, have long memories, display slow decay, exhibit a different chemistry again and have a different criticality in maintaining different biological functions.

The proportions of these components comprising a streamflow will vary, inter alia, with changed attributes of rainfall patterns, altered land uses and antecedent catchment wetness associated with CC (Schulze, 2005b). Because of their variable residence times and lags, as well as origins within a catchment and associated properties of water quantity and quality, these streamflow components need to be modelled explicitly as distinct individual components (and not by empirical hydrograph separation) if certain key questions in their responses to climate change, and IWRM in general, are to be answered satisfactorily.

ii. The Need to Distinguish Clearly Between Landscape Based and Channel Based Processes

Within morphologically similar landscapes, hydrological processes down hillslopes tend to be spatially repetitive; with the hillslope elements of the catchment being the generators of streamflow in its different forms. Under conditions of climate change the landscape processes, which may have been modified by land use and land management, need to be modelled separately from channel processes by water budgeting procedures which have to account, inter alia, for both the feed-forwards and feedbacks associated with the drivers and buffers of climate change, and which are not always fully understood and/or accounted for by the process representations in hydrological models (Schulze, 2005b).

Channel processes, on the other hand, tend to be additive with catchment size, are attenuated by channel characteristics of slope, shape and roughness as well as by transmission losses to floodplains, banks and alluvial beds and by open water evaporation, are manipulated by engineering works (e.g. by abstractions, diversions and impoundments, Figure 2.7) and need to be modelled hydraulically (as distinct from hydrologically) with often complex equations describing relatively well understood relationships.

If catchment and channel processes, as well as those of transitional hydrological features (riparian zones, wetlands and estuaries) are not separated explicitly in models used for climate change impact studies, and IWRM in general, scaling problems emerge in parameterisations between smaller and larger catchments (Schulze, 2005b).

iii. The Ability to Model Hillslope Processes

Be it artificial fertilizer or pesticide movement through the soil, or the different generation mechanisms of streamflow, sediment production, or water demand by land uses in riparian vs. upslope areas, these are all influenced by hillslope hydrological processes and pathways, and are dependent upon the thresholds, rates, accumulations and feedbacks of the different elements making up the landscape, viz. the crest, scarp, midslope, footslope and riparian zone. The hillslope elements and their accumulative downslope interactions need to be represented in a conceptually sound manner in order to answer prognostically the many questions which catchment managers will be posing in the near future, and which are likely to be exacerbated by CC (Schulze, 2005b).

iv. The Ability to Model the Different Processes which may Dominate in Different Climatic Regimes

Globally the wide climatic range with annual precipitations ranging from < 50 mm to > 5 000 mm; with some falling as low intensity rain, some as snow, and some associated with high intensity convective storms, coupled with high intra- and inter-seasonal variability of the precipitation; and with the precipitation falling onto terrain ranging from steep montane to undulating hills to plains, all implies a highly variable spatio-temporal conversion of precipitation to streamflow, as well as a regionally and seasonally variable partitioning into overland flows, subsurface stormflows, baseflows or snowmelt, where the groundwater table may or may not be "connected" to the channel, depending again on season and location.

The above all point to the hydroclimatic environment being a complex one. Further examples of this complexity include: Groundwater recharge, for example, may be through the soil matrix in more humid areas or by channel transmission losses in more arid zones. Evaporation losses, on the other hand, may be dominated by riparian zone processes, or by transpiration, or by soil water evaporation, depending on climatic and vegetation regimes, or be influenced strongly by slope and aspect. Further, mountain catchment hydrology can be dominated by poorly understood precipitation; altitude gradients in terms of rain vs snow, rainfall intensities, numbers of rainfall days and event magnitudes, all of which change with elevation.

Climate change will alter the spatial patterns of hydroclimatic regimes. Directly, or by surrogate means, the various processes which under present climatic conditions may be present or absent, or dominate in specific hydroclimatic regimes, will have to be encapsulated in model process representations for effective modelling of climate change impacts on water resources (Schulze, 2005b).

v. The Ability to Model Different Intensities of Land Management Practices

Identical broad land cover categories can produce significantly different hydrological responses, depending on the level or intensity of management practice. Thus, for example, grassland in overgrazed vs. well managed condition can change sediment yield by a factor of 4 or more (Schulze, 2003); annual crops grown on fields with vs. without contour banks or under conventional vs conservation tillage practices can yield significantly different magnitudes of runoff, in addition to changing the partitioning of rainfall into storm- vs. baseflows occurring (Schulze, 2005b).

In an era when streamflow reduction activities, best management practices, payments for ecosystems goods and services and the „polluter pays" principle are integral components of IWRM, and where in future land uses are likely to shift spatially and adaptive management practices applied, models have to be able to simulate differences in land use management (as against only land use) practices realistically under present and, importantly, future climatic conditions.

vi. The Need for a Daily Time Step, Conceptual-Physical, Process-Based and Non-Linear Dynamic Response Model

In order to simulate potential impacts of global change on hydrological processes and responses (the top component in Figure 2.7), in line with the model requirements discussed above, such a model would need to fulfil the following criteria (Schulze, 2005b):

- be conceptual, in that it conceives of a one or multi-dimensional system in which important processes and couplings are idealised
- be physical, to the degree that the physical processes are represented explicitly through observable variables (Eagleson, 1983)
- the model should, at minimum, be functional (i.e. threshold based, with initial and boundary conditions) in its process representation (Schulze, 1998)
- hydrological processes should account for present and future climate exchanges of water vapour, CO2 and energy (e.g. precipitation attributes, streamflow generation responses, evaporation and transpiration together with its CO2 driven feedbacks for modelling plant-soil interactions of future climates),
- which are then modified by characteristics of the

- – soil (surface infiltrability, subsurface transmissivity of soil water and water holding capacity);
  - – land cover and land use/management (e.g. with above-ground attributes related to intra-seasonal biomass; surface attributes of soil protection by litter/mulch or of tillage practices; below-ground attributes relating to root distribution); and
  - – topographic features of the landscape (e.g. accounting for differences in altitude, slope, aspect, toposequence and topographic position).
- The model should reproduce non-linear and scale-related catchment responses explicitly, where these are associated with
  - – spatial heterogeneity in surface processes (e.g. topography, soils, rainfall, evaporation, land use);
  - – non-linearities responding to episodic events (e.g. rainfall), to cyclicity (e.g. seasons, evaporation), to hillslope processes (both on surface and below surface), to immediate responses (e.g. surface runoff from connected impervious areas; saturated overland flow), rapid responses (e.g. stormflow), ephemerality (e.g. discontinuous flows), more continuous responses (e.g. groundwater movement) and/or delayed responses (e.g. baseflow);
  - – thresholds required for surface and subsurface streamflow processes to commence; and
  - – dominant processes changing with scale or human interference (fig 2.2), including emerging properties (e.g. advection) and representations of disturbance regimes (e.g. drainage of fields, changes in streamflow regimes resulting from dam construction/abstractions/return flows), of gradual changes in land use intensification over time (e.g. agriculture and urbanisation), or of extensification (e.g. cropping in climatically marginal areas, or overgrazing impacts), or abrupt changes (e.g. those resulting from fires or flooding).
- As such the model should essentially be devoid of the need for calibration or parameter optimisation, since such parameters may be meaningless when extrapolating into future climates or future land uses.
- Furthermore, for most operational modelling, simulations should take place at daily time steps since the day is the shortest universal natural time step. Furthermore, climate variables from GCMs are now output at daily values, diurnality encapsulates (albeit not perfectly) many hydrologically related processes which are important in climate change studies (e.g. evaporation, transpiration and many discrete rainfall events), many operational decisions are currently, and in future climates will also be, made according to daily conditions (e.g. irrigation, reservoir operations) and daily climate data for present/historical climate conditions are readily available from a wide network of stations.
- Model output for impact studies of projected climate change within a framework of IWRM will have to address potential management conflicts across a range of spatial scales from upslope vs downslope conflicts, upstream vs downstream conflicts to those within vs. between Water Management Areas (Schulze, 2005b).

The major advantage of such daily time step, conceptual-physical, non-linear response models is that, because of their high level of process representation and physically based boundary conditions, they may be used with confidence in extrapolations involving "what-if" scenarios of hitherto unmeasured land management strategies, extreme events or climate variability which may be associated with global change and which are essential ingredients of IWRM.

6.3 A Suggested Hydrological Model for Simulating Potential Impacts of Climate Change: The ACRU System

The ACRU agrohydrological modelling system (Schulze, 1995; Schulze and Smithers, 2004 and updates), which has been, and is currently being, used extensively in IWRM and climate change studies in southern Africa, complies with many of the premises and principles outlined above and is centred around the following objectives (Figures 2.8 and 2.11):

- It is a daily time step, conceptual-physical model,
- with variables (rather than optimised parameters values) estimated from physically based characteristics of the catchment,
- and the model revolves around daily multi-layer soil water budgeting.
- As such, the model has been developed into a versatile total evaporation model (Figure 2.11), structured to be highly sensitive to perturbations in climate drivers and to land cover, land use and management changes on the soil water and runoff regimes. Additionally, its soil water budget is responsive to supplementary watering by irrigation, to changes in tillage practices, enhanced atmospheric CO2 concentrations or to the onset and degree of plant stress.
- ACRU is a multi-purpose model which integrates the various water budgeting and runoff production components of the terrestrial hydrological system (Figures 2.12 and 2.13). It can be applied as a versatile model for design hydrology (including flow routing through channels and dams), crop yield modelling, reservoir yield simulation, ecological requirements, wet-

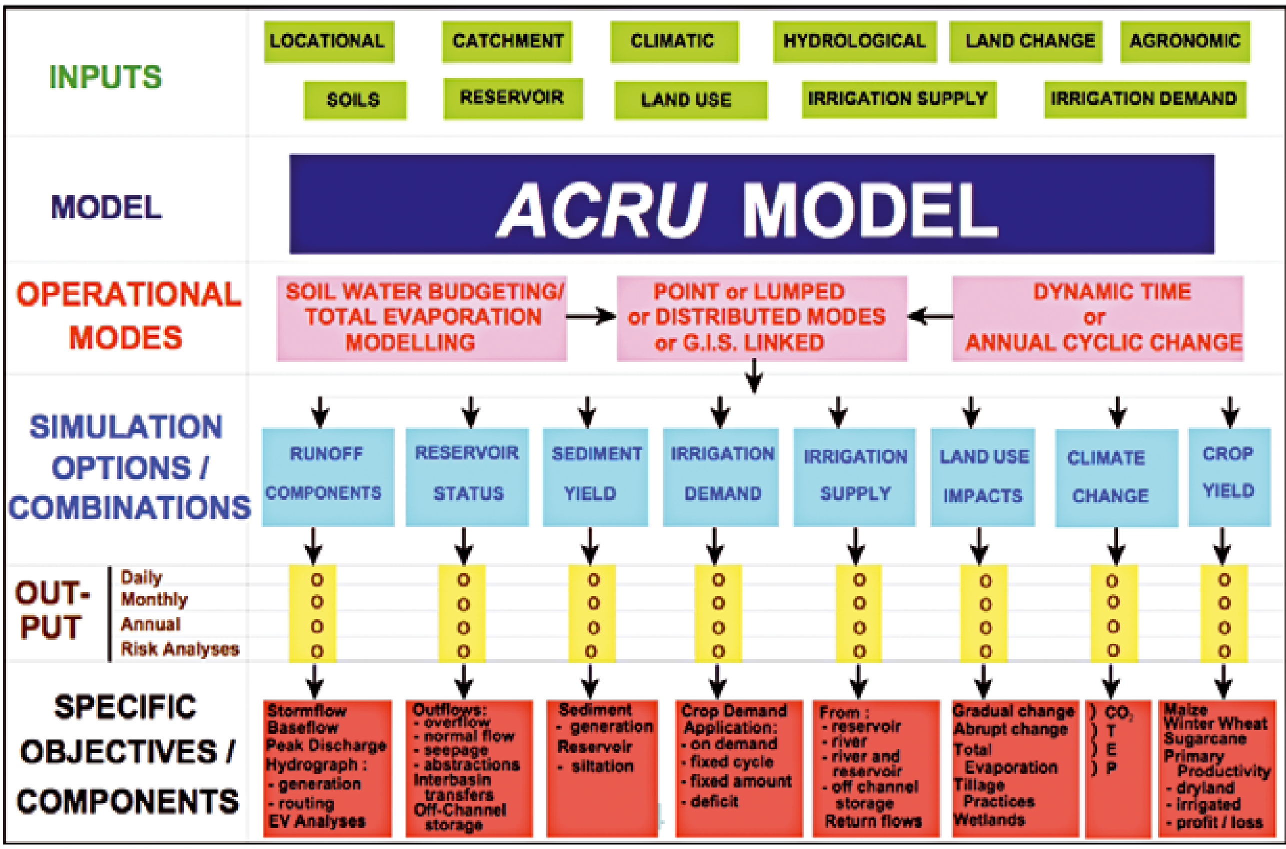


Figure 2.8: The ACRU agrohydrological modelling system: Concepts (after Schulze, 1995)

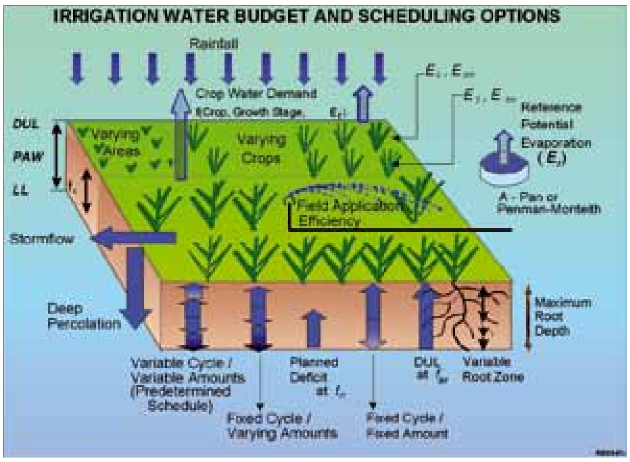


Figure 2.9: Schematic of Irrigation Water Demand and Scheduling Options Available in ACRU (after Schulze, 1995 and updates)

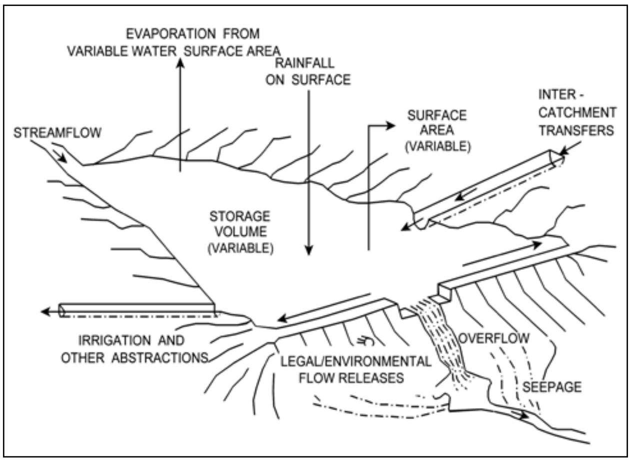


Figure 2.10: Schematic of the Reservoir Water Budget in ACRU (after Schulze, 1995)

lands hydrology, riparian zone processes, irrigation water demand and supply (fig 2.9), water resources assessment(fig 2.10), planning optimum water resource utilisation/allocation, conflict management in water resources, climate change impacts and land use impacts - in each case with associated risk analyses (Schulze and Smithers, 2004).

- ACRU can operate at multiple scales, either as a point model or as a lumped small catchments model; on large catchments or at national scale as a distributed cell-type model with flows taking place from "exterior" through "interior" cells according to a predetermined configuration, with the facility to generate individually requested outputs at each subcatchment's exit.
- The model includes a dynamic input option to facilitate modelling of hydrological responses to climate or land use or management changes over time, be these long term/ gradual changes (e.g. urbanisation or climate trends), or abrupt changes (e.g. construction of a dam), or changes of an intra-annual nature (e.g. crops with non-annual cycles).

- The ACRU model has been linked to the Southern African National Quaternary and Quinary Catchments Databases for applications across a range of scales in the RSA, Lesotho and Swaziland.

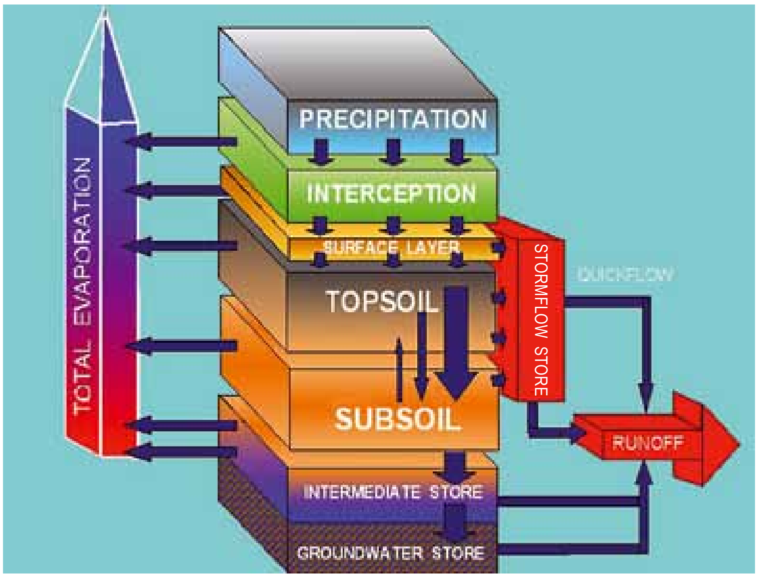


Figure 2.11: The ACRU agrohydrological modelling system: General structure (after Schulze, 1995)

The requirements for the “ideal” model with which to assess potential impacts of climate change in the real world of complex and holistic water management, have been shown to be both manifold and stringent. The ACRU modelling system meets many, but not all, of the criteria/ requirements discussed in the previous section. Its conceptual-physical structure, operating on a daily time step and its multi-purposeness are without doubt attributes weighing in favour of its selection as a suitable model, as is its potential as a tool in resolving water management conflicts (e.g. land use impacts, water allocation, impacts on/ of wetlands and reservoirs) at scales from small catchment to national, as testified by over 100 references (see Schulze and Smithers, 2004).

The model still requires improved process representations of interflow and baseflow releases, channel transmission losses and the addition of more water quality components. Despite these limitations, ACRU is, nevertheless, considered to be a modelling system highly suitable for evaluating impacts of climate change on the hydrology and water resources of southern Africa and elsewhere.

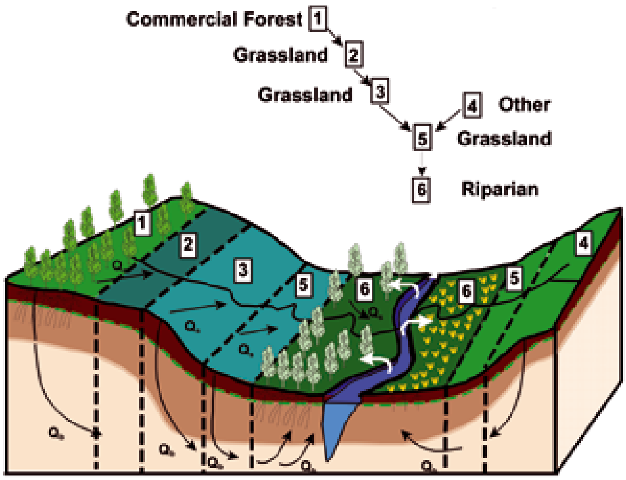


Figure 2.12: Hillslope and Riparian Zone Processes in ACRU (after Meier et al., 1997; Schulze, 2000b)

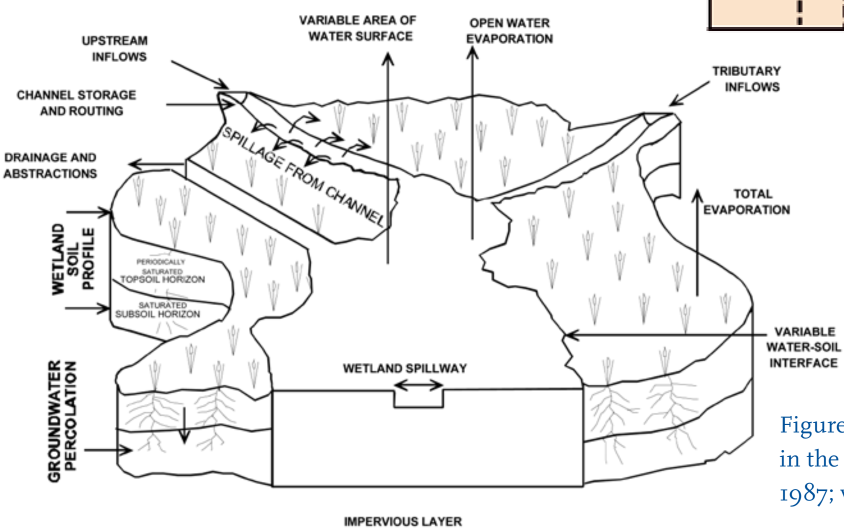


Figure 2.13: Concepts, Processes and Assumptions in the ACRU Wetlands Module (after Schulze et al., 1987; with modifications by Schulze, 2001d)

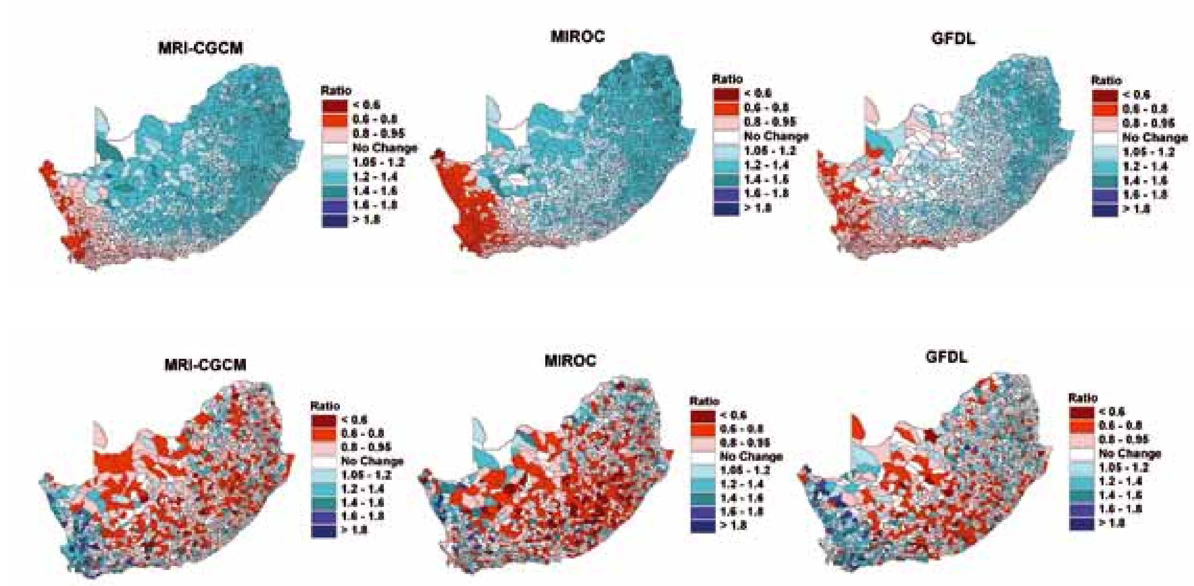


Figure 2.14: Ratio changes of mean annual precipitation (top) and the CV of annual precipitation (bottom) between intermediate future AR4 climates and the present

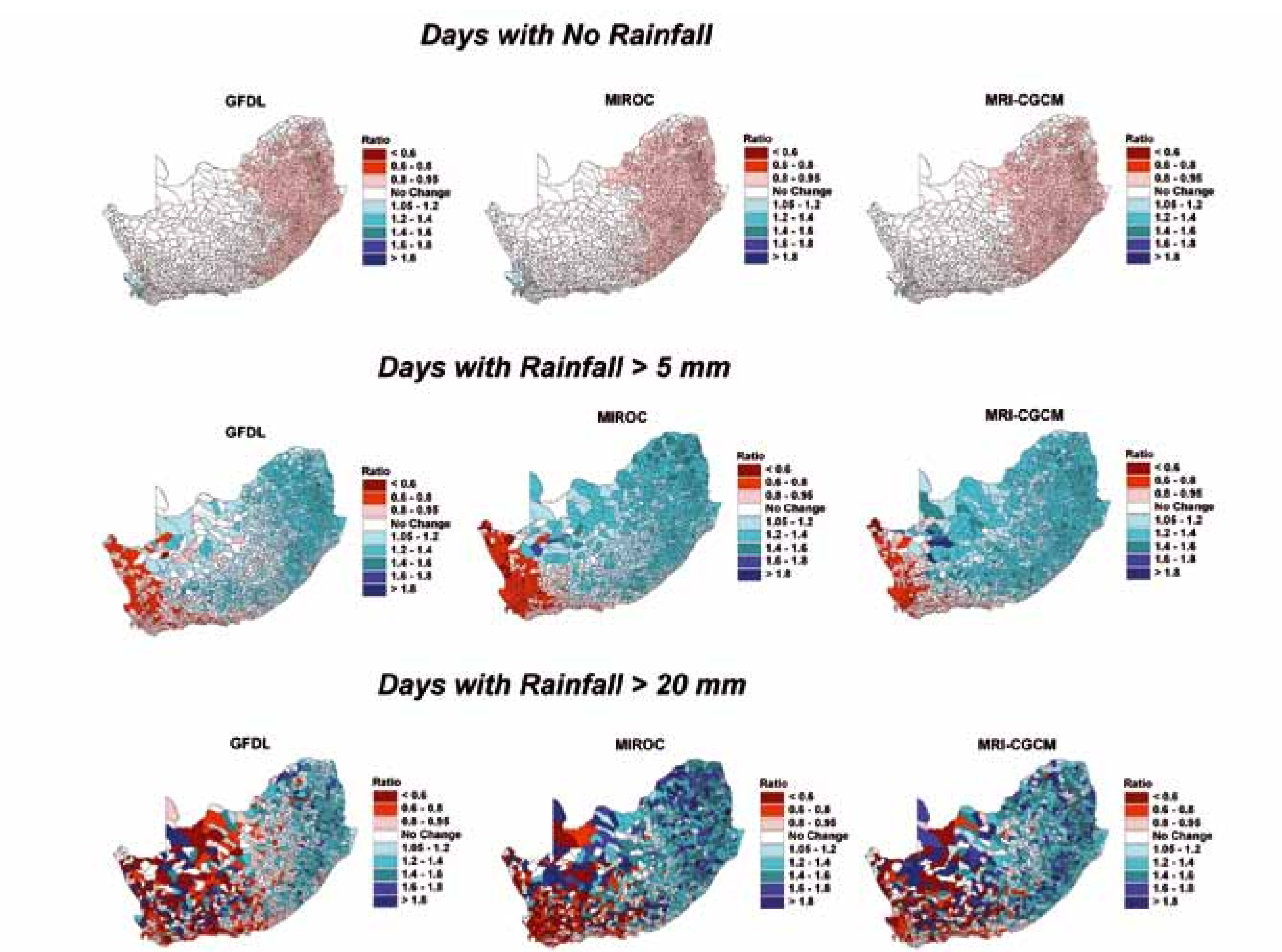


Figure 2.15: Ratio changes of days without/with rainfall between intermediate future AR4 climates and the present

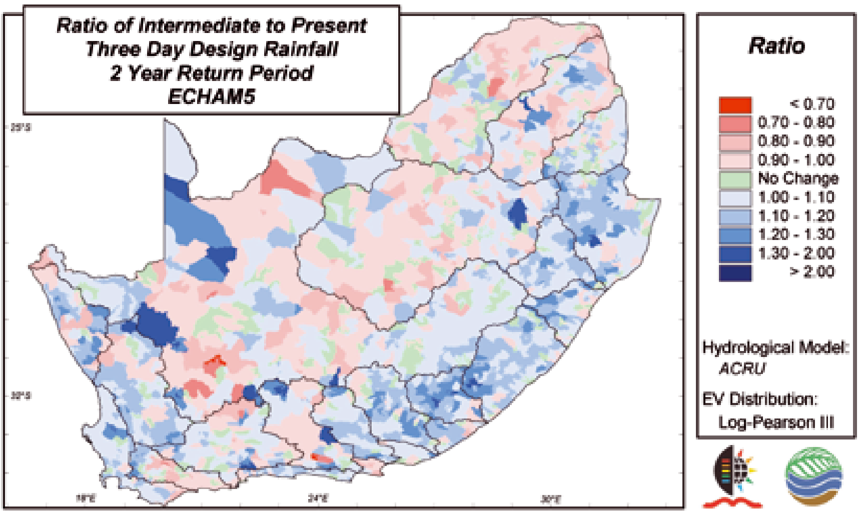


Figure 2.16

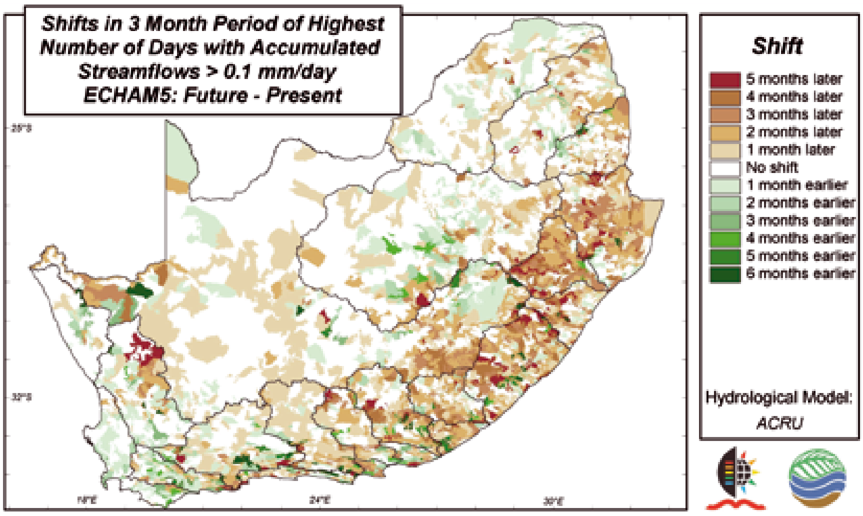
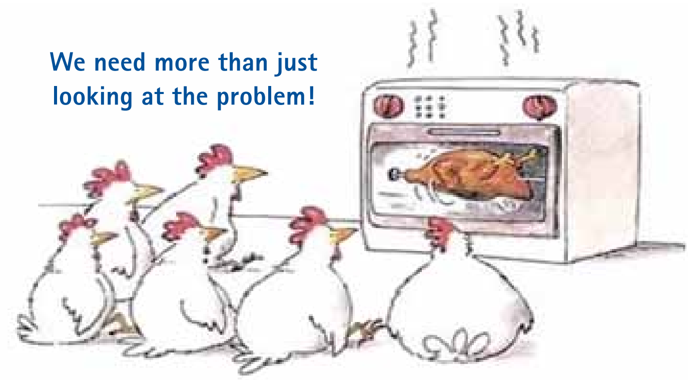


Figure 2.17

7. Adaptation issues



Having outlined some concepts of IWRM and its links to climate change, then raised issues of scales and model requirements for assessing potential impacts of perturbations of future climates on hydrological responses, the last major section now addresses the question of adaptation to climate change in the water sector. The focus is on experiences from South Africa, in the first instance outlining the existing legislation within which to strategise on adaptation, then focusing on the challenges of uncertainties, followed by some observations on adaptation by local water experts, the presentation of a conceptual framework on adaptation for South Africa and, finally, outlining some limitations to adaptation.

7.1 The Legislative Framework Within Which to Address Climate Change – The South African Case

A distinction has to be made between overarching national level legislation pertaining directly or indirectly to adaptation to climate change, and more water sector specific legislation.

a. The Overarching National Level Buy-in to Adaptation

i. The Constitution of South Africa of 1996

The South African state's commitment to adaptation is already imbedded in its Constitution in which it is stated that everyone has the right to access to "sufficient food and water" (Ch 2 Bill of Rights, Section 27b) and that everyone be provided with the right to an "environment that is not harmful to their ...well-being" and to have "the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures" (RSA, 1996).

ii. The National Climate Change Response Strategy of 2004

More explicit than the Constitution regarding adaptation issues is the National Climate Change Response Strategy (NCCRS) which was published in 2004 by the Department for environmental affairs and Tourism. The NCCRS has the mandate of providing a roadmap for national climate policy based on the obligations to the Kyoto Protocol as well as publishing a National Adaptation Plan which focuses on vulnerable and/or threatened ecosystems and their associated goods and services (including those related to water) that support many livelihoods and maintain South Africa's environmental health and integrity (DEAT, 2004).

iii. The Climate Change Research and Development Strategy of 2008

Additionally, a Climate Change Research and Development Strategy with a 10 year vision is currently (2008) being completed by the Department of Science and Technology. This strategy aims at fostering/enhancing South Africa's knowledge on CC impacts, overall awareness and capacity as well as resilience in response to CC.

b. The More Specific Water Sector Buy-in to Adaptation

In addition to overall policy related buy-in in South Africa, the foundations for more water sector specific IWRM-CC links have been laid by the following:

i. The National Water Act of 1998

IWRM is firmly entrenched in the South African National Water Act (1998), which clearly declares "the need for the integrated management of all aspects of water resources and, where appropriate, the delegation of management functions to a regional or catchment level so as to enable everyone to participate" (NWA, 1998). Consequently, IWRM is the guiding principle of societal, environmental and economic needs and constraints, now and under conditions of climate change, which

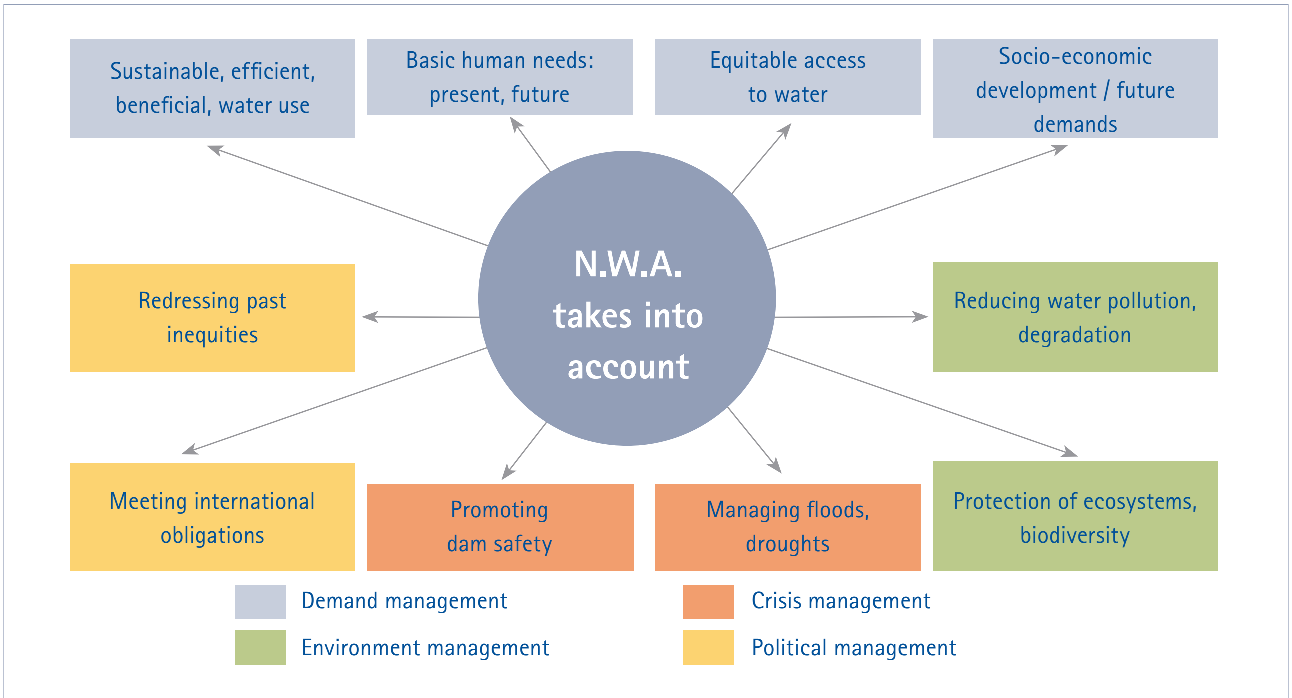


Figure 2.18: The South African National Water Act interfaces

is recognised explicitly in the Act (fig 2.18). Further, a strong emphases on, for example, top-slicing water for the human and ecological reserve as well as for downstream international obligations; assessments of streamflow reduction activities, also on water licensing/allocation; participatory processes that lead to equitable and sustainable development; and on flood/drought related disaster and risk management, provide a range of new challenges to the scientific and policy fraternities in regard to adaptation strategies to CC in the water sector.

ii. The National Water Resource Strategy of 2004

The objective of the 2004 National Water Resource Strategy (NWRS) is to take the National Water Act from legislation to a more practical implementation phase via obligatory IWRM which is to be effected through institutions such as Catchment Management Agencies and Water User Associations. Climate change features in the NWRS in the recognition that "the future will not be a simple extension of the past", with the interdependence of land use and climate change seen as the "two key influencing factors with respect to resource availability" (NWRS, 2004). Climate change is viewed in the NWRS as a cause of changing patterns of the water cycle by magnitudes and in variability as yet unknown. It is anticipated that the 2009 update of the NWRS will be more specific on issues of climate change in the water sector.

7.2 Adaptation in Practice

a. Challenges to Adaptation in the Water Sector

i. Many uncertainties remain in regard to potential impacts of climate change on water resources

Many uncertainties still remain regarding the question of potential impacts of climate change. These start with uncertainties surrounding emission scenarios of greenhouse gases, onto uncertainties revolving around the sensitivity of the global climate to enhanced emissions. The uncertainties then "explode" at each successive "downward" level, e.g. from global to the regional scale changes, climate variability, then to the possible biophysical impacts and eventually to resultant socio-economic impacts.

Uncertainties from climate science include questions on

- what is "background noise" (i.e. natural variability) vs what is already deemed a clear "signal" (i.e. trend) in an already variable climate?, or
- despite major advances (IPCC, 2007a) different GCMs still only predict general directions (e.g. increase in temperature), and sometimes they even still give mixed signals, and certainly varying magnitudes of change (e.g. on rainfall), and not yet with high degrees of certainty regarding changes in variability, which are often more important in hydrology than changes in magnitude, or on more relevant local (vs. global) change, although all these uncertainties are gradually being reduced (IPCC, 2007a).

More specifically in hydrology there are further uncertainties, specifically

- stochasticity, i.e. the inherent unknowable randomness (e.g. of rainfall);
- ignorance, i.e. our still imperfect knowledge of hydrological system dynamics; and
- scaling issues, e.g. on
  - spatial upscaling of process representations from points where measurements are made, to homogeneous landscape elements such as the hydrological response unit (HRU) in hydrology, to the 3-dimensional representation of a hillslope or small catchment, to disaggregated catchments (such as the Quinary Catchments in southern Africa), to regional sub-delineations (such as the Quaternary Catchments), to larger, often sub-continental scale international basins and, finally, to global scale representations, for example, at the scale of the perturbations associated with the El Niño-South Oscillation phenomenon; and equally on (Schulze, 2005a),
  - climatic downscaling of GCM information to regional climate change manifestations, which include local topographic forcing and, eventually, to the scales at which hydrological models operate, which is usually at the daily time step and at the Quaternary Catchment and, ideally, the Quinary Catchment spatial scale (Schulze, 2005a).

In regard to issues on climate change and hydrology it may also be argued that

- hydrological modelling (through incomplete process representations) and hydraulic design are, at best, still only approximations, with safety factors often built in, or that
- Africa has more pressing water problems than those related to climate change, or that
- impacts of the water engineered landscape (e.g. irrigation, channel modifications, water storages/releases or interbasin transfers) are generally greater than those of land use changes (e.g. afforestation or urbanisation) which, in turn, can be greater than those resulting from climate change (Schulze, 2001), but with a high dependence on the scale at which the water resources are managed.

Despite the uncertainties which abound, there are sound reasons to adopt a no-regrets approach to the potential hydrological impacts of climate change, because hydrological structures

- have long lead times from the planning to the operational phases,
- are often designed for lifespans of 50 - 200 years,
- are very expensive and essentially irreversible investments, which are designed to operate close to their design limits in times of major floods or droughts (Schulze, 1997).

Furthermore,

- since the hydrological system amplifies any changes in rainfall, the assumption of climatic stationarity, used in current hydrological design, is invalidated;
- the public expects efficient, robust designs to function into a future which may include climate change; and
- decision makers need to justify their decisions on water structures now, and for local hydroclimatic conditions, and cannot stall decisions until more certainty is available on climate change (Schulze, 2003).

To ignore the need to adapt to possible impacts of climate change on hydrological responses is, therefore, done at ones' own peril.

ii. What General Observations can be Made on Water Resources Management and Climate Change: Experiences from the "Thukela Dialogue"

The Thukela Dialogue was one of 17 national, basin and regional "dialogues" commissioned globally by the International Dialogue on Water and Climate (DWC) in seeking to bridge the information gaps between the water and climate sectors and so improve our capacity to cope with, and adapt to, the impacts on water management of increasing climate variability and change. Held in South Africa, and with a strong regional flavour, it nevertheless brought to the fore important general findings relating to adaptation strategies in the water sector which were captured by Schulze (2003) and are summarised in a wider African context below:

Water resource management (WRM) is not an end in itself. Rather, in an African context, it is a tool for equitable and sustainable social and economic development, thus is seen as a service to ones nation and its people, and as a tool with knock-on effects on all sectors of society (Rowlston, 2003). Climate change merely adds another layer of complexity to an already complex management of water resources. However, water managers need quantifiable information with which to

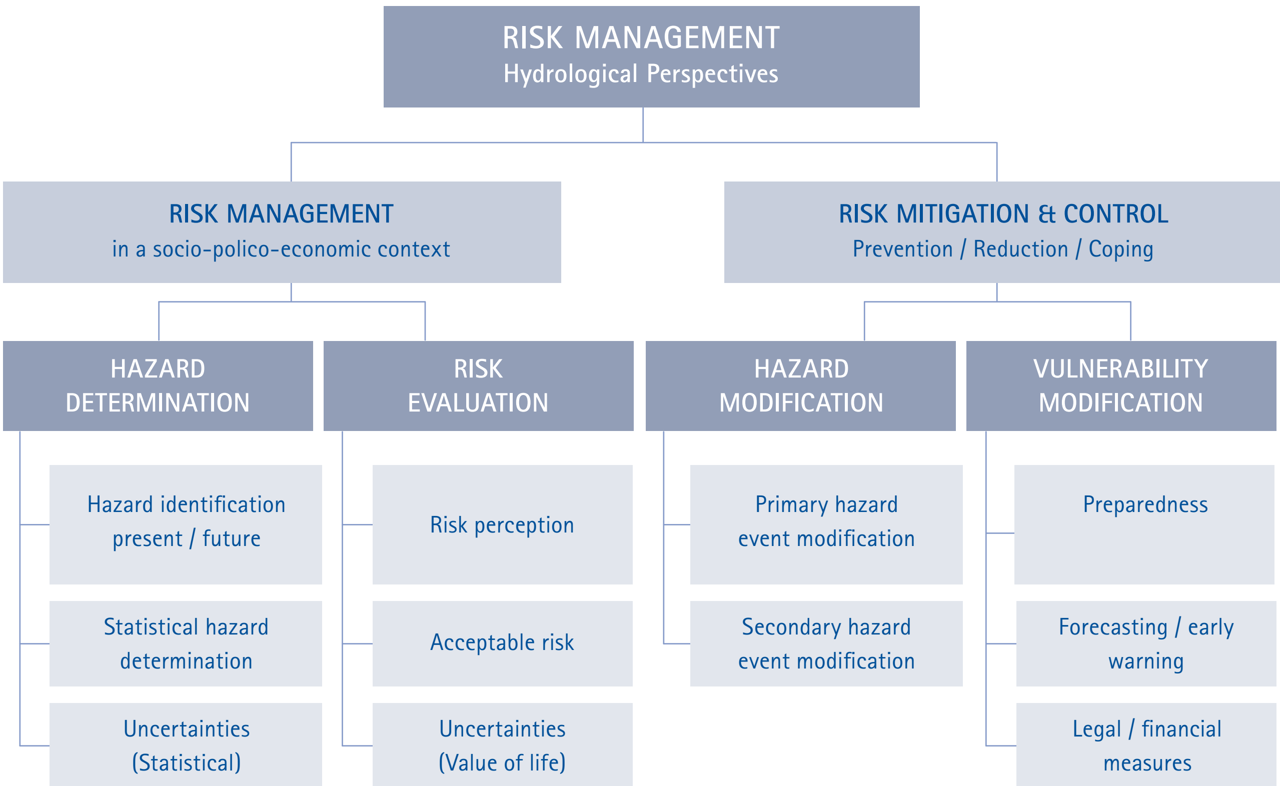


Figure 2.19: Risk management

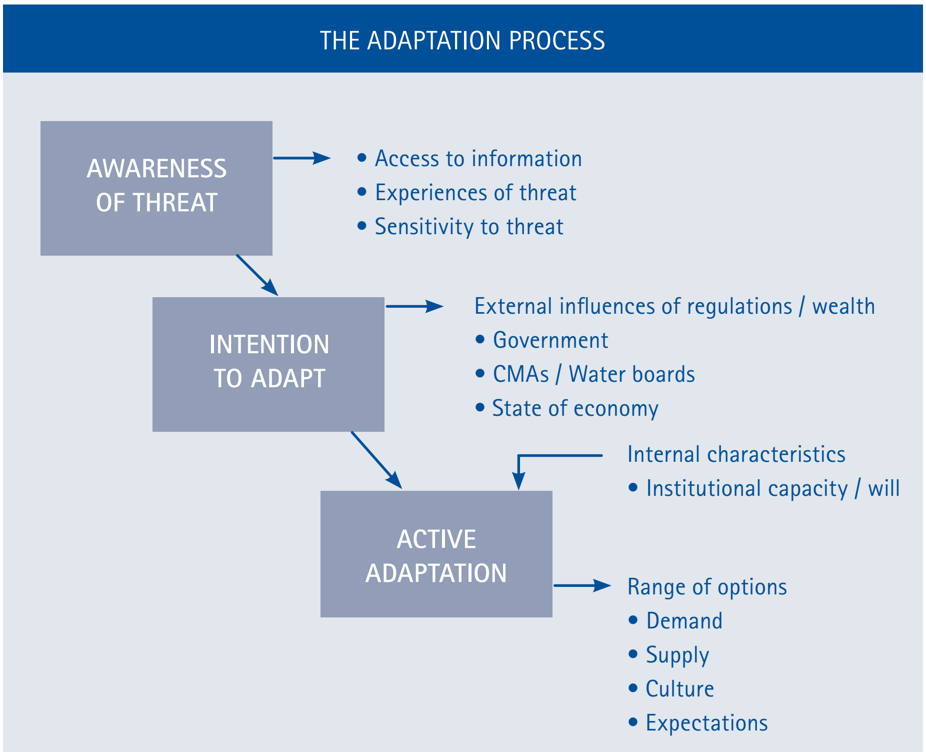


Figure 2.20: The adaptation process

make decisions, and not merely vague projections. Therefore, two clear requirements are for increased skills and quantification of uncertainties from the GCMs of future possible climates (Rowlston, 2003).

WRM does, however, already need to consider on how best to react to the still relatively low skills projections from GCMs and how best to use them in cost-effective contingency planning. Not only magnitudes and directions of climate change need to be known, but also when, where and how national departments of water affairs should start to apply their WRM strategies when bearing climate change in mind (Rowlston, 2003). The effects of climate change, and compensating for it, will have to be built into the full water management cycle. These effects include a more complete conceptualisation than that at present of the non-linearities in the different hydrological zones in ones country, in which the interactions of a changed climate will vary in their sensitivity and be dynamic (Schulze, 2003). Further, consideration should be taken of, for example, the implications of climate change and water licensing based on streamflow reduction impacts (partly because the distributions of natural baseline land covers against which land use impacts are assessed will change, and partly because land uses per se will undergo geographical shifts), or alterations to reservoir operating rules under changed climatic conditions.

It is important to place groundwater on the agenda when climate variability and climate change are being considered because of its potential value in future water resource management. Changes in climate will affect both ground- and surface water resources through changes in primary rainfall/runoff/recharge responses. However, there will also be additional changes on secondary effects on groundwater through changes in vegetation, land use and rates of evapotranspiration (Cavé et al., 2003). Amongst the biggest challenges for groundwater hydrologists in light of climate change will be improvements to overall water management, including the conjunctive use of surface- and groundwater and the use of groundwater as a back-up to systems dependent on surface waters, as well as improving methods for managing and controlling possible declines in the water table through artificial groundwater recharge (Cavé et al., 2003). An important consideration in light of climate change is that groundwater smoothes the short term variations which occur in surface water responses because of the delayed lag in its response to individual rainfall events and thus, unless it is already being overexploited, it can provide a reliable buffer to short term changes in rainfall patterns (Cavé et al., 2003).

From a design engineering perspective climate change is highly challenging in an African context, particularly in light of generally declining hydrometeorological networks and because the accuracy of computations on extreme events is a function of the quality, period and length of the records; much of which is lacking in Africa. Already the variability in the range of hydrological extremes in much of Africa is high, with some areas more vulnerable than others, and these patterns are likely to change. Furthermore, spatially the return periods of rainfall and runoff do not coincide (mainly as a result of differences in soils, land uses and/or antecedent soil moisture conditions within a catchment) and such spatial "discrepancies" could well become more complex with climate change (Smithers and Schulze, 2003). Many further questions on design hydrology arise with climate change, e.g. whether extremes are already becoming more extreme and more frequent; how one handles outliers of extreme events (which under present climatic conditions already pose serious problems in analysis); whether the frequencies of different types of extreme weather events (e.g thunderstorms vs tropical cyclones) are likely to change, such that the 15-year return period may shift to becoming the 5-year return period because a different type of rainfall is occurring. Furthermore, how does the design engineer factor the above issues into the present designs of structures which are built to last well into the era of predicted climate change? (Smithers and Schulze, 2003). Design hydrology will, therefore, have to be re-evaluated in the light of climate change and the anticipated enhanced climatic variability associated with this change.

In regard to policy and legislation links to future changes in climates, present legislation in most countries already contains sound principles on coping with the vagaries of inter-annual variability of climate and the hydrological amplifications thereof. The prospect of climate change, however, makes it more important than ever to apply the present legislation on water, conservation or mountain catchments more intensely, more timeously, at more locations and with more focus (Rowlston, 2003). However, a more direct adaptation of policies, strategies and legislation may still be required as a result of the strong likelihood of climate change. Care will nevertheless need to be exercised to ensure that certain adaptation options to climate change, such as water detention in situ on the catchment or planning new irrigation projects, do not run counter to certain current water policies on, for example, streamflow reduction or environmental flow requirements, and an integrated research effort will be required on adaptation (Rowlston, 2003). A special focus is required on the adequacy of government policies on water and disaster management in regard to the rural poor.

Under non-stationary climatic conditions, monitoring is becoming more important than ever, for not only are networks in Africa often sparse, and/or on the decline, and/or the data are of inadequate quality, but present baselines (i.e. benchmarks) against which future changes are quantified need to be established, not only in hydrometeorology, but also for agriculture and other land uses. There is thus a renewed need to monitor where we go from here into an "uncharted" climatic environment (Schulze, 2003).

In regard to agriculture and water in a climate change context, important water related legislation and policy revolving explicitly and implicitly around agricultural land already exists in many countries, e.g. legislation on streamflow reduction activities, on licensing for irrigation, water allocation, riparian zone clearance of aliens or on soil conservation. This confirms that the dynamic interrelationship between water and agriculture under present climatic conditions is already a highly symbiotic one, with any climatic driven impacts on changes in water availability in the soil as well as in the channel affecting agricultural practices and production (e.g. dryland crop yields, irrigation water supplies), while simultaneously any impacts of climate on agricultural practices and production affect water availability (e.g. water use by production forests; Schulze, 2003).

With respect to issues of the environment and climate change, the most critical ecological issue is the maintenance of biodiversity. This has implications in catchment management, both terrestrially and in-channel, which should be researched as an integrated whole, rather than pitching the various issues against each other. There is, as yet, only a very limited understanding of the full impacts of climate change on, for example, aquatic habitats, wetlands functioning or estuaries, or of ecosystem goods and services, with little knowledge as to whether, when and where certain thresholds of tolerance are exceeded in the various environmental systems. From an environmental perspective the effects of climate change will be different terrestrially vs in-stream. One reason is that the many and significant inter-basin transfers and other in-channel systems such as dams, have changed in-stream characteristics quite markedly, additionally, terrestrial hydrological responses, where irrigation is a major water user, have changed. Both terrestrial and in-stream responses will be very different under climate changed conditions (Schulze, 2003). The method of determining the environmental flows of water in streams for maintenance of downstream aquatic integrity by, for example, mimicking near-natural flow regimes to include minor and major floods, flow durations etc. under "average" and "drought" conditions will need to be reviewed to take into account possible effects of climate change for, if nothing else, climate change will result in new intra- and inter-seasonal equilibria of flow and sediment regimes, and therefore of new dynamic baseline conditions.

b. A Framework for Water Sector Adaptation to Climate Change: The Case for Assessing Secondary and Tertiary Impacts

As a point of departure from this topic, core reasons for adopting an appropriate adaptation strategy remain those of the IPCC's six statements in their 2001 report (IPCC, 2001), viz.

- Climate change cannot be totally avoided;
  - Anticipatory and precautionary adaptation is more effective and less costly than forced, last-minute, emergency adaptation or retrofitting;
- Climate change may be more rapid and more pronounced

ADAPTATION ISSUES AND THE WATER SECTOR . . . AT A GLANCE

Too Much Water, too Little Water

- Are recent floods / droughts signs of CC?
- Impacts will be on water quantity and quality; magnitudes and timing
- Uncertainties exist, but enough is known for action

Sectoral and Regional Aspects

- Water is a core sector, cascading to
  - agriculture
  - health
  - recreation
  - fisheries
  - navigation
  - biodiversity

Imbedding Adaptation

- Climate change needs to be integrated
  - agriculture
  - land use development
  - tourism
- We want win-win solutions with other benefits
- Achieve frameworks which are
  - cost effective
  - flexible
  - modifiable

Time and Multi-Stakeholder Dynamics

- Strategy implementation takes time
- Adaptation interactions are
  - international
  - national
  - provincial
  - local
- Have to involve
  - business
  - civil society

National Practices

- Need national policy frameworks on CC
  - long term planning
  - policy research
  - institutional development
  - infrastructure investment
  - education
  - information exchange

Research and Policy Support

- Need local scenarios
- Need 20 year timeframes
- Reduce uncertainties
- CC vs CV
- Couple climate with hydro models
- Maintain networks
- Vulnerability research
- Ecosystems research

Figure 2.21: Adaptation issues and the water sector . . . At a glance (EEA, 2007)

than current estimates suggest, with unexpected events possible;
  – Immediate benefits can be gained from better adaptation to climate variability and extreme atmospheric events;
  – Immediate benefits also can be gained by removing maladaptive policies and practices; and
- Climate change brings opportunities as well as threats, with future benefits also resulting from climate change (IPCC, 2001).

On a more local front, it was again the "Thukela Dialogue" (Schulze, 2003) which highlighted numerous key points on adaptation:

- First, it needs to be reiterated that while many sectors in South Africa are vulnerable to the effects of climate change, the water sector is arguably amongst the most vulnerable. Furthermore, hydrological responses to climate change may be regarded as an integrator among the many sectors dependent upon, or affected by, the spatio-temporal distribution of water, e.g. rainfed agriculture, irrigated agriculture, the insurance industry, the transport industry, disaster management, rural/community health, or industrial development (Rowlston, 2003).
- Questions which arise from the above include the following:
  – What mechanisms exist within central, provincial or local government to co-ordinate the various responses to climate change?
  – What mechanisms are in place to prevent a particular sector from adopting a climate change related strategy which may be of short-term benefit to that sector, but be detrimental to other strategies, or in the national interest?
- In adopting adaptation strategies for South Africa, scien-

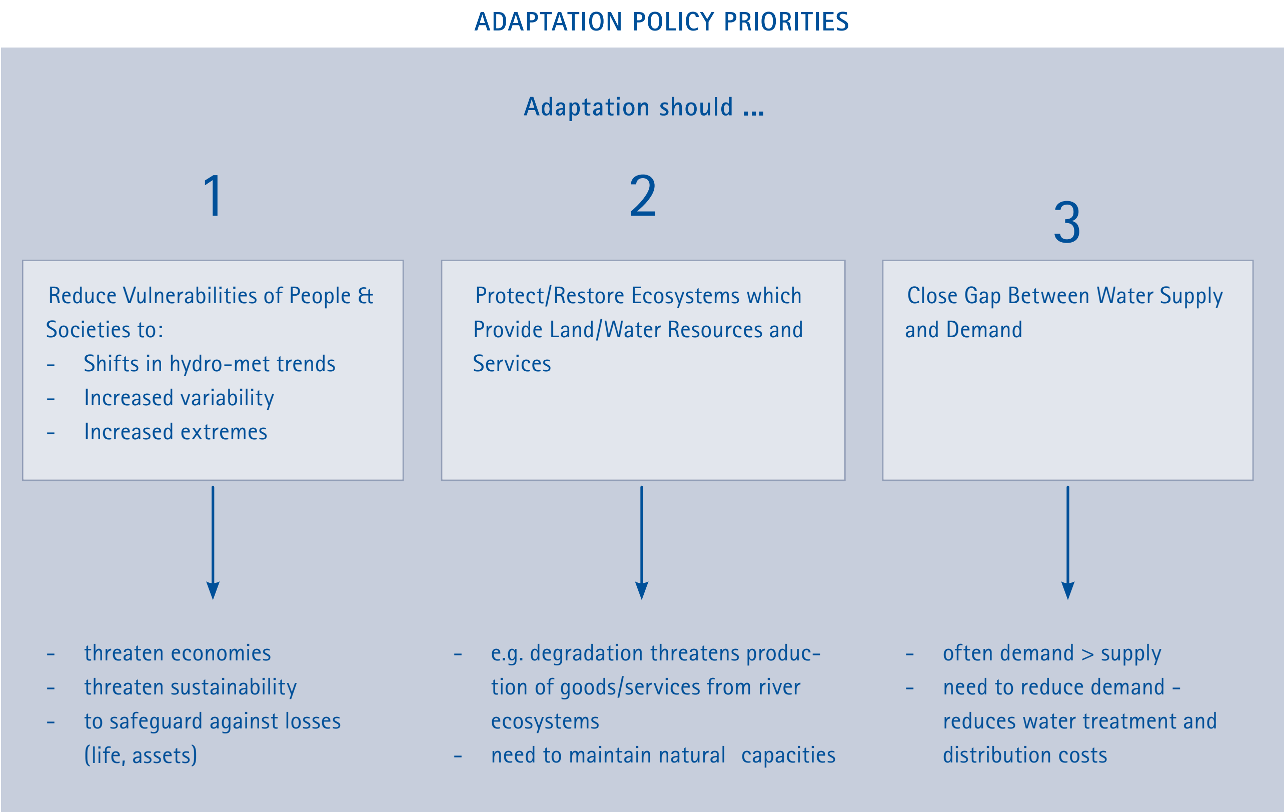


Figure 2.22: Adaptation policy priorities (Bergkamp et al., 2003)

tists and government need to move from only considering primary impacts of climate change to placing far more emphasis on modelling secondary and tertiary effects on hydrology (Schulze, 2003):

– Primary impacts of climate change on hydrological responses focus, for example, on changes in total/averaged flows, e.g. MAR.
– Secondary impacts still deal only with fluxes of water per se, and would consider, inter alia, modelling changes in the seasonality of streamflows with respect to flow duration curves, supply and demand for various sectors (e.g. irrigation or domestic), with knock-on effects on water pricing/licensing, and effects on water resources infrastructure, including sizing of reservoirs, curtailment rules, or reservoir maintenance, changes in rainfall and streamflow variability at inter-annual and intra-annual time scales, effects of changing vegetation dynamics on resultant hydrological responses, regional amplification of variability, persistencies of flows above or below selected thresholds, changes in the magnitudes and frequencies of extreme events related to both floods and droughts, including peaks over threshold analyses, changes in groundwater recharge, or effects of land use on water availability, mainly through alterations in the partitioning of rainfall into stormflow and baseflow (Schulze, 2003).
– Tertiary (higher order) impacts of climate change go beyond fluxes of water per se to include assessing changes in water quality (for example of sediment yield; water chemistry, i.e. N, P or salinity; or biological status of water using E.coli as an indicator), or of water temperature (as a driver of changes to aquatic habitats or of water-borne diseases), and consequences thereof in purification costs or human health, as well as changes

in aquatic ecosystems and effects of climate change on ecosystem goods and services or on in-stream flow requirements (Schulze, 2003).

- Furthermore, climate perturbations, responding through the hydrological system, may result in
  - changes in the potential for conflict over shared rivers where rivers form international boundaries, or especially where rivers discharge downstream from one country to another,

  as well as
  - changes in water problems for the poor, who often live either on floodplains which may become more prone to flooding in the future, or alternatively, live along higher lying watershed boundaries where streams tend to be more ephemeral and may become even more so in future (Schulze, 2003).

c. A Framework for Water Sector Adaptation to Climate Change: The Example of South Africa

An initial framework of needs and requirements when planning strategies to cope with, and/or adapt to, impacts of anticipated climate change and potentially enhanced climate variability has been developed for South Africa following a series of workshops with water resource managers, water policy makers, consultants, agricultural experts, environmentalists, socio-economists and other scientists (Schulze, 2005a). It consists of a matrix of

- three time frames of change, viz.
  - long term strategic, i.e. decadal, such as climate change;
  - medium term tactical, i.e. seasonal, such as a forecasted drought; and
  - short term operational, such as flood events/disaster management

  versus
- three sets of needs and requirements, or instruments of coping, viz.
  - legal and policy;
  - institutional and management; and
  - information, research and monitoring.

For the long term strategic decision time frame involving climate change the following were highlighted (Schulze, 2005a; Table page 69-70):

- On Legal and Policy issues a strong focus was placed on
  - rendering the National Water Resource Strategy more climate change "aware" than it was at present, and also more specific in regard to climate change, as well as
  - emphasising more strongly effective risk management policy.
- On Institutional and Management needs and requirements in regard to adaptation to climate change, the foci were
  - effective operations of Catchment Management Agencies, for them to take cognisance more seriously of climate change,
  - risk management,
  - governance, and
  - enforcement of existing policies.
- On Monitoring, Research and Information needs to be considered in light of projected CC impacts on the water sector, issues highlighted included
  - a review of hydrometeorological networks in South Africa in light of detecting impacts of climate change which may already be present,
  - the availability of quality data,
  - building capacity in the field of climate change studies,
  - improving both the climate and hydrological models used in impact studies, and
  - educating, training and communicating with relevant targeted groups (e.g. politicians) on climate change issues (Schulze, 2005a).

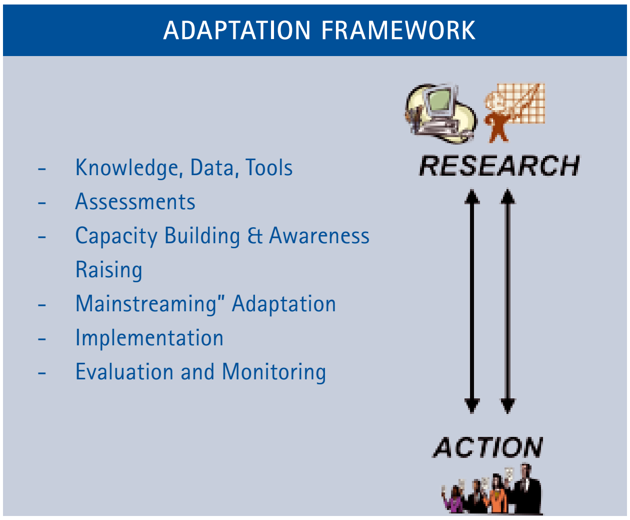


Figure 2.23: Adaptation framework

Legal and policy

International
- Mobilise the implementation of the Kyoto Protocol in southern Africa
- Re-negotiate international water agreements with neighbouring states in light of Climate Change (CC)

National Water Resource Strategy
- NWRS must recognise the importance of CC and cater for it more explicitly
- NWRS needs to be updated routinely to address new finding on CC impacts
- NWRS needs to be provided with more "teeth" re. CC
- More co-participation required in the NWRS with political, social and economic sectors
- NWRS needs to define clearly the boundaries of accountability and responsibility between
  - national
  - CMA/WMA
  - District Municipality and
  - city specific issues

National Climate Change Response Strategy (NCCRS)
- Department of Environmental Affairs and Tourism (DEAT) needs
  - a more strategic approach to CC
  - greater commitment to apply the NCCRS
  - to develop more specific legislation re. CC

More Specific Policy Requests/ Requirements
- Re. Risk Management
  - review existing national disaster management legislation re. CC, e.g. fires, floods, droughts
  - floodplain zoning and management; spatial considerations; urban areas
  - dam safety and spillway standards
  - property risk policies re. predicted floodlines with CC
- Legislate more specifically on demand management
- Develop a policy on long-term hydrometeorological monitoring

Enforcing/Policing policy
- Enforce existing policies more effectively

Institutional and management

Catchment Management Agencies (CMAs)
- Establish CMAs which will operate effectively re. Integrated Water Resources Management (IWRM), including CC
- Improve co-ordination within and between CMAs re. activities, methodologies
- Ensure wider stakeholder participation

Risk Management
- Revise/improve risk management (RM) plans re. floods, droughts
- Set up an advisory to advise land owners in flood prone areas re. risks, flood probabilities
- Implement a State insurance scheme for disasters
- Develop policy on water restrictions

Governance
- Establish incentive schemes for initiatives in co-operative governance
- Ensure that institutions adapt to CC findings at all levels of government and the private sector

Infrastructure
- Need improved strategic plan for new infrastructure re. WRM
- Construct more dams in relevant areas to make provision for additional water needs with CC
- Review systems operations re. assurance of supply

Water Licensing
- Exercise more care in evaluating/awarding of licences to water users in light of CC
- Raise tariffs to fund effective IWRM

Enforcement/Compliance
- Enforce compliance with regulations/laws
- Increase enforcement re. controlling groundwater abstractions

Monitoring, research & information

Monitoring

1. Networks & General

- Revise the entire network of rainfall and streamflow gauges re. detection of CC, and adapt, if necessary
- Identify and maintain high quality flow gauges
  - with long records
  - on unaltered catchments
- Measure streamflow at all strategic points
- Improve monitoring of land use change
- Improve and regularly update WARMS database for better application in granting water use licences
- Create an independent Earth Systems monitoring agency for South Africa

2. Data

- Ensure integrity of streamflow data
- Achieve greater integration of hydroclimatic and related databases
- Make data more readily available
- Ensure transparency in sharing data

Research

1. General Capacity Building

- Build more capacity re. CC research
- Create incentives for new techniques in CC related water research

2. Climate Models

- Improve CC projections for SA, to increase confidence levels in their application to WR
- Improve downscaling techniques for application in SA

3. Hydrological Modelling

- Improve process representations in hydrological models for application in a range of hydroclimatic regimes (e.g. semi-arid zone)

4. Specific Research Requirements

- Climate change scenario analysis re. hydrological responses
- Regional impacts of CC on WR
- Storage of water in disused mines, aquifers
- Reducing evaporation from dams
- Forecasting of hydrological attributes (e.g. streamflow irrigation requirements) from near real time to days to seasons ahead with rapid dissemination of results
- Optimise crop selection according to climate forecasts
- Undertake baseline hydrological studies for use in impact studies (including control sites)
- Quantification of components of the hydrological cycle
- Identification of high-risk, vulnerable areas
- Surface water/groundwater interactions
- Explore deeper groundwater systems for emergency supplies in droughts
- Status of catchment soil moisture/vegetation using remote sensing
- Water demand patterns
- Alien plant control re. water use

Information

1. Education/Training

- Education of politicians and other decision makers re. CC and its impacts (awareness)
- Education in Earth System Science at high schools
- Training workshops based on latest findings of CC and WR

2. Communication

- Require an effective communication policy to be developed re. CC, including media, schools
- Improved communications between scientists, engineers and policy makers

Table 2.2: Needs and requirements with regard to adaptation to climate change in the South African water sector, as identified by stakeholders (Schulze, 2005a)

Many of the policy and management issues summarised in Table 2.2 are nothing more than putting into practice more effectively what is already on paper. Furthermore, a number of the research issues identified have in fact been, or are currently being, addressed in a number of research projects in South Africa.

d. Where to Now? Limits to Adaptation

Clearly, planned adaptation is required in the highly sensitive water sector in addition to autonomous adaptation. Many workshops worldwide, as well as the findings of the IPCC (2007b), have signalled the water sector's awareness of a potential additional stress arising from climate change. A clear intention by stakeholders in the water sector to adapt is now required. Iindeed, the stage is now set for active adaptation to be implemented, through policy instruments and through implementation by practitioners operating at international and national levels, as well as at local levels.

There are, however, limits to adaptation which need to be appreciated (Figure 2.24):

- Nature sets physical limits, for example, by provision of a finite water resource, be it surface water and/or groundwater, in situ and/or transferred.
- The socio-economic and political scene, particularly in developing countries, sets other limits to adaptation which are usually government or governance related, be they
- financial constraints,
- feasibility limits, where adaptation options may be feasible, but are not effected because of country or region specific political, or social, or environmental pressures, or
- capacity limits, both within organisations in general and of individuals tasked with effecting adaptation policies on the ground (Figure 2.24).

Despite the logical appeal of, and belief in, whole catchment water management, initiatives in IWRM have often neither lived up to their expectations nor reputations (Frost, 2001). These problems are likely to be exacerbated by anticipated impacts of climate change and the associated uncertainties. Barriers to IWRM, particularly in LDCs but not exclusively so (as identified for example by Falkenmark et al., 1999; Frost, 2001; Schulze, 2001), should not, however, become barriers to timely and adequate adaptation strategies related to CC. Such barriers include the following:

- Sectoralism often exists within and between government departments, manifested by the fragmented nature of institutional structures, with often different functions and

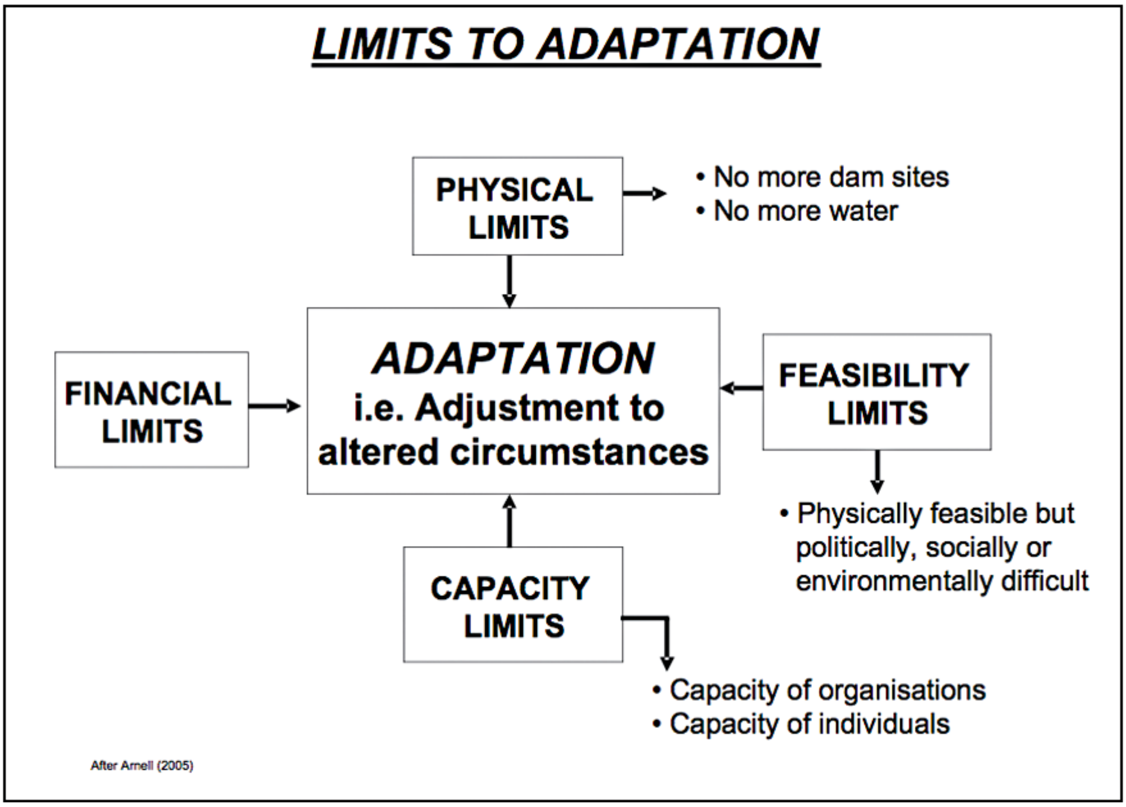


Figure 2.24: Limits to adaptation (after Arnell, 2005)

political agendas in regard to climate change responsibilities where these link up with risk management, resource management or international water obligations.

- There is frequently a lack of clearly defined overall climate change related strategies in the water sector, including management objectives and mechanisms for delivery, and there is a tendency for being "high on rhetoric and talk" at the strategic level, but "low on action" on the ground.
- Water in a future climate is often viewed as a potential source of conflict, not only between sectors (e.g. agriculture vs urban demands), but also within a sector (e.g. dryland vs. irrigated or commercial vs. subsistence agriculture water needs), and in particular with respect to the right to water, and tensions between upstream vs. downstream water users and uses. The latter is a special concern in the interactions between IWRM and climate change because of an inherent "asymmetry" (Frost, 2001) in the interactions, where
  - downstream users are affected by direct upstream responses to CC, e.g. through changes in abstractions, impoundments, flow reductions through intensification of agricultural land uses and/or deterioration of water quality, while
  - upstream users can only be affected by downstream users indirectly by political pressures on future water uses, legislation or compensatory payments/levies for ecosystems goods and services.
- Deficiencies in research, and hence information, pertaining to CC related impacts and vulnerabilities, frequently exist as a result of the application of outdated climate scenarios, inadequate downscaling and use of inappropriate models, insufficient spatial information, a lack of willingness among organisations to share data and information and/or networks of information flows being inadequate.
- Deficiencies are evident in capacity with regard to effecting the integration between climate change and water resource management.
- Deficiencies come to the fore in understanding adequately the dynamics between land management and climate change, including how the use of land impacts on the quantity and quality of water, but more specifically on how to cope with/adapt to changing hydrological conditions with respect to inter-annual climate variability or more permanent climate change;
- Deficiencies are frequently evident in water management options under future climatic conditions, in regard to its storage, treatment, equitable allocation and distribution as well as best practice in implementing demand management.
- Deficiencies occur in stakeholder involvement, e.g. with unstructured approaches to public consultation in regard to CC, a lack of trust between CC scientists and stakeholders, often centred around issues of uncertainties of what the future may bring (and when), or the presence of strong pressure groups and lobbies.

IWRM aims at finding long term sustainable ways to cope successfully with the particular environmental pre-conditions in a certain region, while simultaneously satisfying societal needs by balancing different functions of water (now and in future) with different sectors (e.g. environmental, agricultural, industrial) and stakeholder groups, who may range from policy makers to local landowners (Falkenmark et al., 1999). One of these environmental preconditions is in the realm of climate and by implication, therefore, climate change. Climate change introduces new players to water management (e.g. climatologists, adaptation strategists) as well as new dimensions (e.g. non-stationary climate baselines, uncertainty analysis). Implicitly and explicitly the impacts of climate change transcend virtually all facets of IWRM shown in Figure 2.2, and particularly in LDC situations, be they from a water demand vs. supply perspective, or from an in-stream vs off-stream ecological focus, or from an institutional/governance angle.

Within the water sector, IWRM presents itself as a sound conceptual and practical medium with which to embrace the additional stressor which impacts of climate change present. Despite its shortcomings, IWRM provides a framework within which to research and evaluate a range of policy and practical choices for adaptation and it offers the opportunity to assist in assessing the risks and options of environmental, social and economic policy makers by re-connecting people to water issues within their catchment through consultative processes, stakeholder participation and partnership options in an uncertain future.

Bibliography

Appleton, B., Kabat, P., Bates, B., Hellmuth, M.E., Bullock, A., Connor, R., van Schaik, H., Veraart, J.A., Hoff, H., Alcamo, J., Schulze, R.E. and Droogers, P. 2003. Climate Changes the Water Rules: How Water Managers can Cope with Today's Climate Variability and Tomorrow's Climate Change. International Dialogue on Water and Climate, Wageningen, The Netherlands. pp 105.

Arnell, N.W. 2005. University of Southampton, UK: Personal communication.

Bugmann, H. 1997. Scaling issues in forest succession modelling. In: Hassol, S.J. and Katzenberger, J. (Eds) Elements of Change 1997, Session One on Scaling from Site-Specific Observations to Global Model Grids. Aspen Global Change Institute, Aspen, CO, USA. pp 47-57.

Cave, L., Beekman, H. and Weaver, J. 2003. The impact of climate change on groundwater resources. In: Schulze, R.E. The Thukela Dialogue: Managing Water Related Issues on Climate Variability and Climate Change in South Africa. Report to International Dialogue on Water and Climate. University of Natal, Pietermaritzburg, RSA, School of Bioresources Engineering and Environmental Hydrology, ACRUcons Report, 44, 85-88.

DWAF 1998. Water Law Implementation Process: A Strategic Plan for the Department of Water Affairs and Forestry to Facilitate in the Implementation of Catchment Management in South Africa. Water Research Commission, Pretoria, RSA, Report, KV107/98. pp 66.

Department of Environmental Affairs and Tourism RSA 2004. A National Climate Change Response Strategy for South Africa, Pretoria.

Eagleson, P.S. 1983. Some problems of parameterization of land surface heat and moisture fluxes. Report to the Fourth Session of the Joint Scientific Committee, Venice, Italy. World Meteorological Organisation, Geneva, Switzerland. 77-97.

Falkenmark, M., Andersson, L., Carstensson, R. And Sundblad, K. 1999. Water: A Reflection of Land Use. Swedish Natural Science Research Council, Stockholm, Sweden. pp 128.

Frost, P.G.H. 2001. Reflections on integrated land and water management. In: Gash, J.H.C., Odada, E.O., Oyebande, L. and Schulze, R.E. (Eds) Freshwater Resources in Africa. BAHC International Project Office, PIK, Potsdam, Germany. 49-56.

IPCC 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability. Intergovernmental Panel on Climate Change, Working Group II Contribution to the Third Assessment Report of the IPCC. Geneva, Switzerland.

IPCC 2007a. Climate Change 2007: The Physical Science Basis. Summary for Policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland.

IPCC 2007b. Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. Summary for Policymakers. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Geneva, Switzerland.

Kabat, P. and H. van Schaik (co-ordinating lead authors) 2004. Climate changes the water rules: How water managers can cope with today's climate variability and tomorrow's climate change. Dialogue on Water and Climate, Netherlands.

Meybeck, M., Vorosmarty, C.J., Schulze, R.E. and Becker, A. 2004. Conclusions: Scaling relative responses of terrestrial aquatic systems to global changes. In: Kabat, P., Claussen, M., Dirmeyer, P.A., Gash, J.H.C., Bravo de Guenni, L., Meybeck, M., Pielke, R.A., Snr., V`r`smarty, C.J., Hutjes, R.W.A. and Lhtkemeier, S. (Eds) Vegetation, Water, Humans and the Climate. A New Perspective on an Interactive System. Springer-Verlag, Heidelberg, Germany. Chapter D8, 455-464.

NWRS 2004. National Water Resource Strategy " Our Blueprint for Survival", 1st Edition. Department of Water Affairs and Forestry, Pretoria, RSA.

Republic of South Africa 1996. Constitution of the Republic of South Africa. Act 108 of 1996, amended on 11 October 1996 by the Constitutional Assembly.

Rowlston, W. 2003. Water policy makers' needs on climate variability and climate change in South Africa. In: Schulze, R.E. The Thukela Dialogue: Managing Water Related Issues on Climate Variability and Climate Change in South Africa. Report to International Dialogue on Water and Climate. University of Natal, Pietermaritzburg, RSA, School of Bioresources Engineering and Environmental Hydrology, ACRUcons Report, 44, 53-56.

NWA 1998. National Water Act. Act No 36 of 1998. Government Printer, Pretoria, RSA.

Schulze, R.E. 1995. Hydrology and Agrohydrology. Water Research Commission, Pretoria, RSA, WRC Report TT69/95. pp 552 (ISBN 1 86845 136 4).

Schulze, R.E. 1997. Impacts of global climate change in a hydrologically vulnerable region: Challenges to South African hydrologists. Progress in Physical Geography, 21, 113-136.

Schulze, R.E. 1998. Hydrological Modelling : Concepts and Practice. International Institute of Infrastructural, Hydraulic and Environmental Engineering, Delft, Netherlands. pp 134.

Schulze, R.E. 1999. Integrated catchment management : Summary of a CEH workshop on ICM. Centre for Ecology and Hydrology, Wallingford, UK. pp 11 (Available from author).

Schulze, R.E. 2000. Transcending scales of space and time in impact studies of climate and climate change on agrohydrological responses. Agriculture, Ecosystems and Environment, 82, 185-212.

Schulze, R.E. 2001. Hydrological Responses at River Basin Scale. University of Natal, Pietermaritzburg, RSA, School of Bioresources Engineering and Environmental Hydrology, ACRUcons Report, 35. pp 102.

Schulze, R.E. 2003. The Thukela Dialogue. The Thukela Dialogue Managing Water related Issues on Climate Variability and Climate Change in South Africa. Report to 'Dialogue on Water and Climate'. University of Natal, Pietermaritzburg, School of Bioresources Engineering and Environmental Hydrology, ACRU cons Report 44.

Schulze, R.E. 2004. What is Integrated Water Resources Management? A Perspective. In: Schulze, R.E. (Ed) Modelling as a Tool in Integrated Water Resources Management: Conceptual Issues and Case Study Applications. Water Research Commission, Pretoria, RSA, WRC Report 749/1/02. Chapter 1, 1-19.

Schulze, R.E. 2005a. Adapting to Climate Change in the Water Resources Sector in South Africa. In: *Schulze, R.E. (Ed)*. Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 27, 423-449.

Schulze, R.E. 2005b. Selection of a Suitable Agrohydrological Model for Climate Change Impact Studies over Southern Africa. In: Schulze, R.E. (Ed) Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 7, 95 - 110.

Schulze, R.E. 2007. Some foci of integrated water resources management in the "South" which are oft-forgotten by the "North": A perspective from southern Africa. Water Resources Management 21: 269–294.

Schulze, R.E. and Perks, L.A. 2000. Assessment of the impact of climate change on hydrology and water resources in South Africa. University of Natal, Pietermaritzburg, School of Bioresources Engineering and Environmental Hydrology Report to South African Country Studies for Climate Change Programme. ACRUcons Report, 33. pp 118.

Schulze, R.E. and Smithers, J.C. 2004. The ACRU Agrohydrological Modelling System as of 2002. Background, concepts, structure, output, typical applications and operations. In: Modelling as a Tool I Integrated Water Resources Management : Conceptual Issues and Case Study Applications. Water Research Commission, Pretoria, RSA. WRC Report 749/1/04. 47-83.

Smithers, J.C. and Schulze, R.E. 2003. Extreme hydrological events in South Africa: Approaches to, and questions we should be asking in, design engineering. In: Schulze, R.E. The Thukela Dialogue: Managing Water Related Issues on Climate Variability and Climate Change in South Africa. Report to International Dialogue on Water and Climate. University of Natal, Pietermaritzburg, RSA, School of Bioresources Engineering and Environmental Hydrology, ACRUcons Report, 44, 63-69.

Chapter 3

Understanding and Responding to Climate

Induced Water Conflict Risks over Transboundary Watercourses in West Africa

By Madiodio Niasse. IRD Institute de Recherche pour le Developpement; Regional water expert. Outgoing GWP West Africa

Contents

1. Abstract

West Africa's climate conditions have significantly deteriorated in the last four decades, a period marked by a significant decline in rainfall and river discharges, and of accentuated seasonal and inter-annual variability. Since the early 1970s, the region's annual rainfall has dropped by 15–30%. The region's major rivers (Niger, Senegal, Volta, Gambia and Lake Chad) similarly experienced a decrease in average annual discharge in the order of 40–60%.

Although climate predictions for West Africa vary significantly depending on the models used, no improvements in climate conditions are expected, and in many scenarios, hotter and drier conditions are predicted with a higher frequency of extreme weather events. Governments respond to decreased rainfall and lower levels of river discharge either by claiming greater control over portions of transboundary river basins which they see as being part of their national territories, or by developing major water infrastructure projects (dam, irrigation schemes, inter-basin transfers) in order to minimise climate impacts on their access to water, often without proper consultation with other riparian sates. The resulting cases of tensions, disputes and conflicts are the focus of this paper. The paper argues that in the West Africa context where countries are highly water-interdependent —the 17 countries that compose the Region share 25 transboundary river/lake basins— climate variability and change increases the risks of inter-state tensions, disputes and conflicts over shared watercourses. It first succinctly explains the theoretical debates to which it seeks to contribute.

The paper further describes the West Africa context in relation to the changing climate conditions it has been experiencing in the last decades. The third section analyses selected cases of disputes, tensions and conflicts around West Africa shared rivers. Cases analysed in the paper include: the middle valley of the Senegal River (between Senegal and Mauritania), the downstream half of the Niger River (between Nigeria and Niger), the Volta River (between Ghana and Burkina Faso), the southern part of the Lake Chad (between Cameroon and Nigeria). The paper then analyses the common features of these cases. Finally, it suggests mechanisms for preventing and managing the risks of climate-induced water conflicts. These suggestions are meant to make transboundary watercourses spaces for cooperation instead of fields of conflicts and tensions

2. Introduction

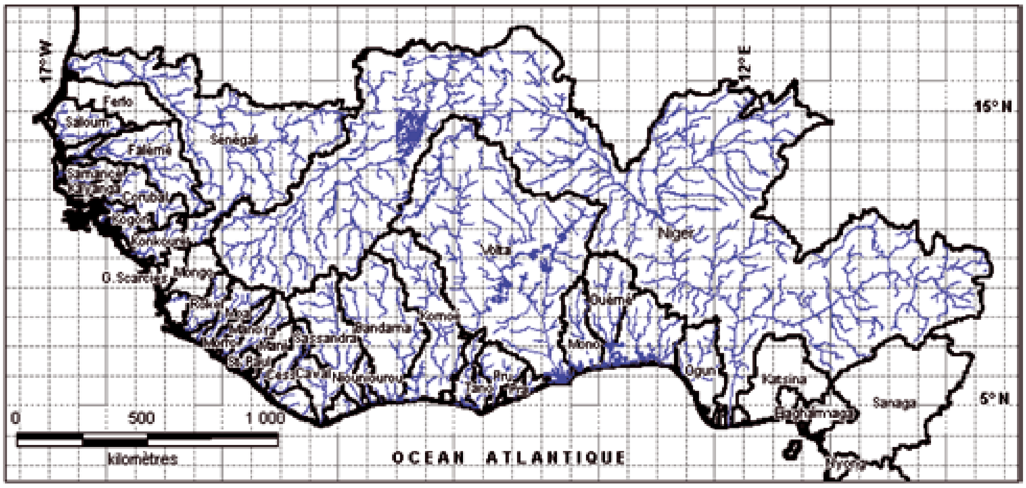


Figure 3.1: Inter-zonal water transfers by major rivers in West Africa

A number of studies carried out in recent years argue that tensions and disputes over water resources rarely lead to open armed conflicts, to “water wars” (Wolf, 2001; Postel & Wolf, 2001; Turton, 2000; Wolf et al, 2003). Records compiled by the Oregon State University on conflicts over transboundary watercourses show that so far relationships between riparian countries can be tense and disputes can occur, but the general rule is that these countries almost always end up finding agreements over modalities for cooperation rather than resorting to violent confrontations Wolf, 2001; Wolf et al 2003).

That said, it must be admitted that with the currently increasing pressure on water resources – as a result of the growing water demand – combined with decreased water availability – as a result of factors such as climate change and variability – risks of water disputes are greater, and could lead to costly regional conflicts (Postel & Wolf, 2001). These factors – growing water demand, reduced water availability as a result of climate change – currently exist in Africa where authors (like Ashton 2002) think that water conflicts are inevitable and could be a cause for regional political instability, unless appropriate measures are taken to prevent these conflicts risks and manage them when they occur.

Indeed, many factors make West Africa a region prone to water conflicts. First, West Africa countries are highly water interdependent. With the exception of the Cape Verde islands, each West Africa country shares at least one of the region’s 25 transboundary river basins. Second, climate change and variability have resulted in severe decline in average annual rainfall and discharge in major river systems. Third, many countries have plans for increasing investments in large water infrastructures, such as dams with the anticipated result of not only increasing water withdrawals but also radically changing natural water allocation patterns between riparian countries.

The climate factor is generally overlooked when analysing the underlying causes of water conflicts. This is because, current efforts at assessing and addressing climate impacts – including on water – are centred at the country level. This is the case for current NAPAs (National Adaptation Plans of Actions prepared by Less Developed Countries in order to enhance their coping strategies and capacity to adapt to climate change) that are developed at the national level, with no complementary regional dimension. In these cases, climate-induced tensions and risks of conflicts between countries are not given due attention in current adaptation efforts.

The West Africa regional dialogue on water and climate and the various studies commissioned as part of this process[1] have shown the need to factor-in risks of conflicts if viable and effective responses to climate change impacts on water are to be found, at least in highly water-interdependent regions like West Africa. Failing to recognise the way and extent to which climate change and variability affect water availability and water quality may not only lead to divergences in the causes of water deficits when they occur, but could also create greater vulnerability as it prevents from anticipating and managing risks of water conflicts.

This paper seeks to help improve the understanding of the sequence of events and patterns leading to heightened conflicts risks around water resources, while paying special attention to the climate factor. It describes cases showing how climate change and variability have ignited tensions and conflicts. Some of these are cases where direct causality between climate change and the conflict risks can be found while in other cases conflict risks are indirect and sometimes long term consequences of the worsening of the climate conditions. On the basis of the West Africa experience, we suggest a set of measures for reducing vulnerability to climate-induced water conflicts.

[1] This West Africa regional dialogue (facilitated by IUCN, GWP, and CILSS) was carried out between 2002 et 2003 as part of the global Dialogue on Water and Climate.

3. Diverging views on the likelihood of intensified conflicts over transboundary waters

There is no agreement on the issue as to whether the current water crisis (water scarcity in particular) increases the likelihood of intensified inter-state competition and conflicts. Two broad opposing views shape this debate. A pessimistic, Neomalthusian view considers natural resources scarcity as the cause of most of the recorded inter-state conflicts — assuming that one considers territories are natural resources (Kathryn et al, 2006). Since the ecological crisis of the 1970s, a growing literature links natural resources scarcity (combined with population growth) as one of the key causes of increased risks and events of both inter-state and community level conflicts (Lipschutz, 1989; Homer-Dixon, 1991). In the same vein, Critchley & Terriff (1993) argue that the likelihood of conflict is high when a resource: (i) Is essential for human survival (as is the case of freshwater); (ii) becomes increasingly scarce in a region (which is the case for water in West Africa as a result of climate change and variability); (iii) can be physically seized or controlled (for the case of water that would be through dams, canals, etc...). On the other hand, the optimistic views either downplay the magnitude of the natural resources crisis (in this case the alleged water crisis) or underline the availability of effective response options to deal with it. In the optimistic view, the imperative for cooperation is stronger than the motivation for conflict (Wolf, 1999; Yoffe et al, 2003).

This paper contributes to this debate by focusing on the analysis of real-life conflict events with the view of helping improve the understanding of the ways multiple underlying factors build up to water-related disputes, tensions and conflict risks. It also analyses the responses that are sometimes deployed to defuse these risks.

4. West Africa context: Impacts of changing climate conditions on water resources

4.1 Water interdependency

One of the West Africa region's most striking features is the stark contrast between wet and arid zones. This contrast is however attenuated by the configuration of the region's hydrographical network. The region's major watercourses (Niger, Senegal, Gambia, Lake Chad hydrographical network) have their sources in high rainfall areas, before flowing through the Sahelian zone, which experiences chronic rainfall deficits. Thus, these watercourses ensure an interzonal transfer of freshwater from wet to arid areas. These transfers, however, create a high level of water interdependency among West African countries. The 17 countries of the region share 25 transboundary rivers: The Niger river basin is shared by 11 countries against 8, 6 and 4 respectively for the Lake Chad Basin, the Volta River and Senegal River. The majority of West African countries have a dependency ration of more than 40%[2]. (see fig 3.2 and 3.3)

4.2 Increased pressure on water

The level of freshwater withdrawal in West Africa only represent 1–3 % of the region's total renewable water resources estimated at more than 1000 billion cubic meters. But if current trends are maintained, the level of water withdrawal will increase six fold before 2025 (GWP, 2000). If West Africa achieves its ambitious development aspirations, the pressure on freshwater resources will be even stronger.

If the trends in climate contexts that occured over the last three decades continue to prevail, West Africa will experience decreased freshwater availability. Compared to previous decades, it is observed that since the early 1970s, the mean annual rainfall has decreased by 10% in the wet tropical zone and by more than 30% in the Sahelian zone (see fig. 3.4) while the average discharge of the region's major river systems dropped by 40–60%.

[2] The water dependency ratio represents the share of a country's total renewable freshwater that is generated outside its borders. The water dependency ratio for countries like Niger and Mauritania is about 90%.

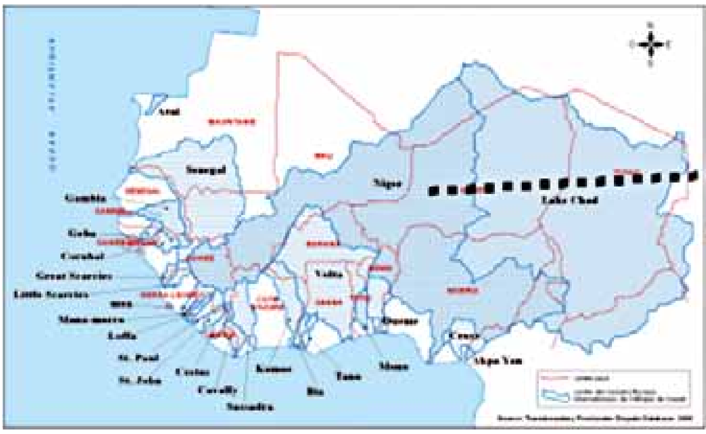


Figure 3.2: Major transboundary basins in West Africa

Figure 3.3: Niger River Basin (Source: WRI, 1999)

This sharp decrease in water availability has been combined with greater uncertainty in the spatial and temporal distribution of rainfall and surface water resources (Oyebande et al, 2002; Niasse et al. 2004).

4.3 Increased investments in water infrastructures in responses to changing climate conditions

In response to the unpredictability of hydro-climatic conditions and as one of the manifestations of the increasing pressure on water resources, West Africa has experienced a significant increase in the construction of large dams. Although when compared with other continents or African regions , the number of large dams in West Africa is currently low (WCD, 2000), there are a relatively large number of projects at various levels of planning (fig. 3.5); a fact which illustrates the frenetic move towards structural responses to climate change in West Africa as the region experiences a growing competition for water. On the Niger River alone, there are no fewer than 20 plans for building new large dams. Among the most advanced projects are: Fomi and Kamarato in Guinea; Kenie, Tossaye and Labezanga in Mali ; Mekrou for Benin and Niger; Kandadji for Niger ; Lokoja, Makurki, Onistha for Nigeria. Countries such as Guinea or Benin have each plans for 4 to 5 large dams which they expect to build in the coming years.

By storing freshwater during seasons and years of abundance and making it available when needed, dams are a means to address scarcity and unreliability of water and achieve a dependable water supply. By doing so, however, they often significantly affect the patterns and modalities of access to water and to other resources depending on it. Therefore, the multiplication of dams increases the pressure on water resources which translates into increased withdrawals and the alteration of flow regimes as a result of the fragmentation of river courses. Dams also pose an issue of equity in access to water and associated resources[3 (next page)]. Depending on their size and location, they affect more or less profoundly the conditions of access to and use of water resources at the entire basin level. In context of lower levels of water development (which is still the case in many basin contexts in Africa), upstream and downstream communities that are riparian to the same river sometimes do not even realise that they share the same waters. This situation radically changes when any of the communities (States

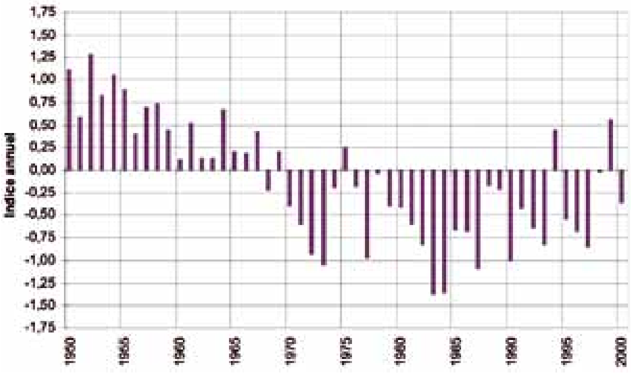


Figure 3.4: Average annual rainfall in the Sahel Regional from 1950 to 2002 (L'Hote et al. 2002)

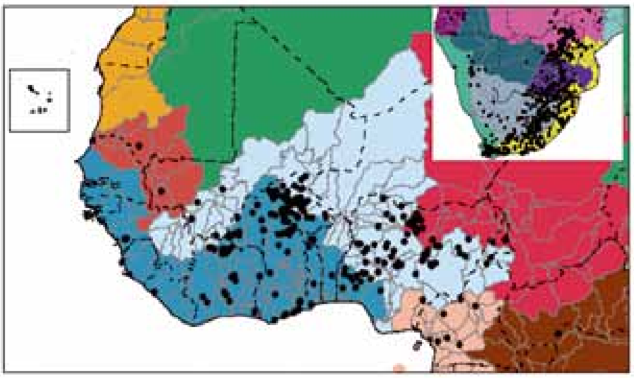


Figure 3.5: Large dams in West Africa (Source: FAO Aquastat 2007)

for example) can significantly alter the quantity or quality of the water flow —through dams, diversion canals, etc... — to the detriment of some and in favour of other users (e.g. riparian dwellers or sometimes even beneficiaries located in remote areas such as urban areas provided with electricity through hydropower development) (NIASSE, 2002) . Therefore, dams "globalise" at the basin level water management issues that would otherwise be addressed at local levels. When dams are built in transboundary basins, resulting changes in water allocation and use often create tensions and conflicts.

5. Climate-induced tensions and conflicts over shared water courses

The significant decrease in water availability – as a result of climate change and variability or as a result of increased levels of water withdrawal – combined with the multiplication of large dam projects and the high level of water interdependency create propitious conditions for tensions and increased conflict risks in West Africa. The following section describes and analyses some of the cases of overt or latent conflicts.

5.1 Mauritania-Senegal: From risks of open armed conflict to the "thickening" of the border

In the Senegal River Basin, 8 of the top ten drought years (estimated on the basis of the volume of discharge in the middle reaches of the river) during the 20th century (1904 to 1984) occurred in the 1970s and in the 1980s (Hollis, 1990). It is in this context that the Senegal River Basin Development Authority (OMVS) was created by Mali, Mauritania and Senegal with the mandate of developing and implementing a major water infrastructure programme, which included the construction of the downstream Diama Dam and the upstream Manantali Dam. In the last quarter of 1988, two years after the commissioning of the Diama and few months after the completion of Manantali Dam (both dams meant to reduce the vulnerability of riparian countries to drought and climate variability), a conflict erupted between Senegal and Mauritania. The tension began when the river started to recede from adjacent floodplains. Senegalese farmers who crossed to the right bank of the river to prepare their fields were chased by Mauritanian border guards. Senegalese authorities retaliated by deporting Mauritanian camel herds who used to spend most of the dry season in the Ferlo region of northern Senegal. A few months later, in April 1989, after a dispute between Senegalese farmers and Mauritanian herders in a territory claimed by the two countries, the Mauritanian border guards killed two Senegalese farmers and held a further 13 in custody. The tension grew, and a series of skirmishes between Senegalese and Mauritanian farmers occured along the course of the river. A few days later, shops held by Mauritanians in small riverine towns and in Dakar were ransacked and looted by bands of youth. In response, hundreds of Senegalese residents were killed in Mauritania, which lead to attacks on Mauritanians in Dakar and other big cities in Senegal, resulting in the deaths of dozens of Mauritanians. The two Governments subsequently imposed a curfew in their respective countries. By the end of June 1989, 75,000 Senegalese and 150,000 Mauritanians had been repatriated, sometimes by air (Horowitz, 1989; Parker, 1991,160; Magistro, 1993). Thousands of black people whose Mauritanian nationality was denied were deported to Senegal. The two countries severed their diplomatic relationships, and the situation remained tense for the rest of the year. The two armies deployed troops along the river, and even exchanges of heavy artillery occured in October and November 1989 (Horo-

[3] On equity issues surrounding dam building, see also: Niasse, M. 2002

Fig 3.6a: Major dams along the Senegal River

witz, op.cit; Parker, op.cit.; Magistro, op.cit.). In 1992, diplomatic relationships between the two countries were restored, but the wounds of the crisis remained for a longer period.

Since then, there is what Seck called a “thickening” of the border as a virtual wall which seems to have been erected along the river (Seck, 1991). This marks a new era as the Senegal River used to be a communication highway regularly crossed by thousands of transboundary farmers residing on one bank of the river while having their farms on the other. The number of these transboundary farmers was estimated at 37,000 in the middle of the 1970s, with 21% residing on the right bank of the river (Mauritanian side) and 79% living on the left bank (Senegalese side) (Seck, 1991). Today, cross-border farming has virtually ceased.

Recent events illustrate the precarious nature of the current situation along the border between Senegal and Mauritania. In June 2000, the Mauritanian government accused Abdoulaye Wade, the Senegalese President, elected three months earlier, of intending to exhume and re-launch the Fossil Valley Rehabilitation Project consisting of diverting water from the shared river to a network of fossil tributaries in northern Senegal. The Mauritanian government reacted immediately by giving Senegalese nationals 15 days to leave Mauritania. President Wade subsequently announced the shelving of the project, which calmed the tension[4].

Figure 3.6b: Senegal River Basin. Source: OMVS

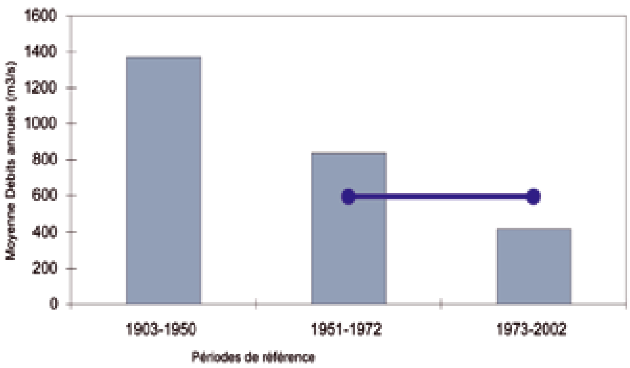


Figure 3.7: Average annual discharge in 1972-2002 is only 25% of that of 1900-1950

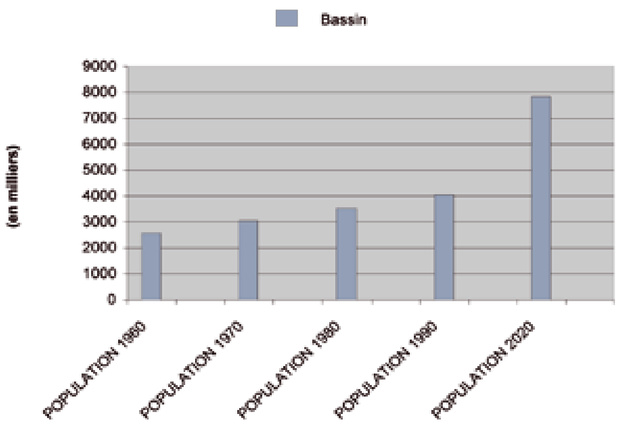


Figure 3.8: Decreased water availability, increased population pressure

[4] See: www.irc.nl/source/weekly/00223.html#senegal-mauritania

5.2 Ghana-Burkina: Suspicion and controversy over the causes of an energy crisis

The Volta River system is increasingly targeted by both Ghana and Burkina Faso to address national development needs. The Akosombo Dam, completed in 1965, created the largest man-made lake in the world with an area of 8,500 km² and a volume of 148 km³ at full reservoir capacity. In 1982, the Kpong Dam was built downstream of Akosombo. Together these two dams have an installed capacity[5] of 1,060 MW (or 95 percent of Ghana's total electricity supply[6]). In an average year, 56% of the waters flowing to the Akosombo Reservoir come from the White and Black Volta (against 44% from the Oti-Pendjari River). In 1998, the water in the Akosombo Reservoir fell below its operating level, resulting in severe power shortages and giving rise to various speculations about the causes of the low level of water inflows to the Akosombo Reservoir (also known as the Volta Lake).

One view was that Burkina Faso had unduly increased water withdrawals in the upper basin through dam building and irrigation development. Indeed, a few years earlier Burkina Faso announced plans to build three large dams on tributaries of the Volta within its territory for water supply to Ouagadougou, the capital city (Ziga Dam), and for power production. At that time, Burkina Faso had already built two large dams and an estimated 1500 small dams in the upper basin of the Volta river. In addition, the irrigated area in Burkina Faso increased from 2000 ha in 1966 to 25000 ha in the late 1990s whereas in Ghana the area irrigated increased from 1000 ha to 7000 during the same period (Andreini et al, 2000; Van de Giesen et al. 2001).

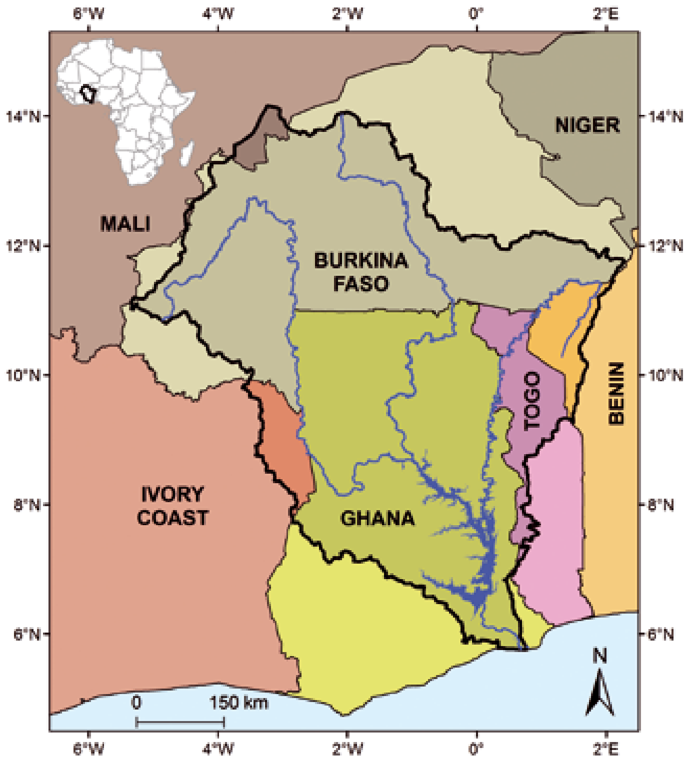


Figure 3.9: The Volta Basin
IRD/BFP Volta using base maps and data from: Dieulen, 2007 and FAO/GeoNetwork (http://www.fao.org/geonetwork/srv/en/main.home).

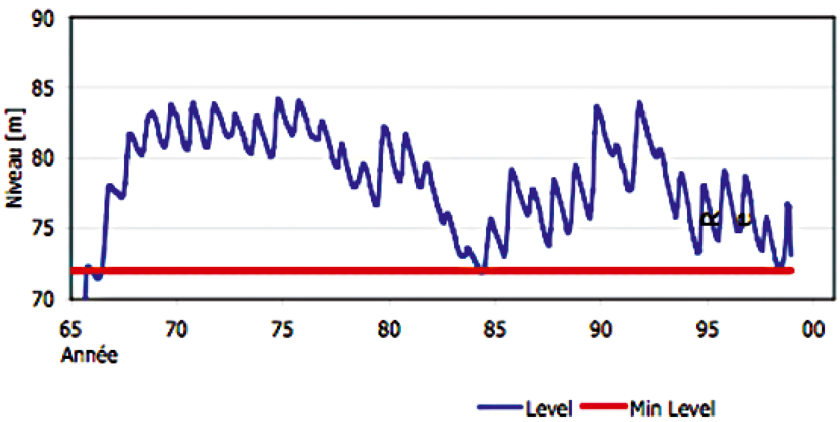


Figure 3.10: Fluctuation in the water level of the Akosombo dam reservoir (Source: Andah, 2003 based on data from GLOWA Volta Project)

5 Sources of information for this section are: Andreini et al, 2000; Van de Giesen et al. 2001.

6 Since 1995 Ghana has identified 17 possible dam sites with an estimated capacity of 1200 MW of power production. Of these, only the Bui dam (on the Black Volta) had reached an advanced development stage before being stalled due to, among other reasons, an intense international anti-dam campaign, the Bui dam site being located in a national park.

While these trends seem to support the feeling that Burkina Faso's investments in water infrastructures were the main causes of water deficits in the lower Volta; the total storage capacity of Burkina Faso's planned and existing large and small reservoirs represents only 1.49 km^3 or less than 5% of the storage capacity of the Akosombo Reservoir (Andreini et al, 2000; Van de Giesen et al. 2001). It is therefore more plausible to link Ghana's 1998 energy crisis to reduced discharge of the Volta as a result of climate change and variability rather than to increased water withdrawals in Burkina Faso.

In addition to water withdrawals, there are two other potential sources of misconception and tensions – all to some extent related to the changing climate conditions in the basin. The first issue relates to alleged water releases from dams in Burkina Faso (particularly the Bagre Dam) resulting in floods in Northern Ghana as was the case in 1999. The second issue relates to the proliferation and migration of aquatic weeds along the Volta river system as well as visible signs of increased water pollution (Gordon et al, 1999). Today it is estimated that 30 percent of the lower Volta is covered by water weeds (mainly Pistia stratiotes, Azolla, and Salvinia) while water hyacinth which has already invaded the Back and White Volta in Burkina Faso represents an even greater threat for the lower reaches of the river basin.

5.3 Niger-Nigeria: For or against the status quo in upstream countries?

Nigeria, which has invested heavily in irrigation schemes and hydropower in the downstream part of the River Niger (Kainji and Jebba dams, 1.6 million hectares of irrigated land, river transport installations, and urban water supply), fears today that the construction of dam projects upstream such as the Kandadji Dam project in Niger and Taoussa Dam project in Mali would lead to reduced inflow to the Nigerian sector. Thus, on several occasions the Nigerian authorities expressed their concern on dam construction upstream and have expressed their opposition to any dam project on the Niger River that would involve a reduction of more than 10% in the volume of inflow received annually in Nigeria[7]. Considering that climate variability over the recent years has resulted in a drop of 20–50% in the average annual discharge of the Niger River (as with most major rivers in West Africa) and taking into consideration the fact that the predicted climate change could lead to further reductions in river discharges, one can justifiable question whether climate variability and change are not going to „withdraw" more water from the Niger river than downstream countries such as Nigeria would consider acceptable (fig. 3.11). One could even fear the occurrence of instances where downstream countries blame upstream dams and irrigation schemes for what is due to climate variations.

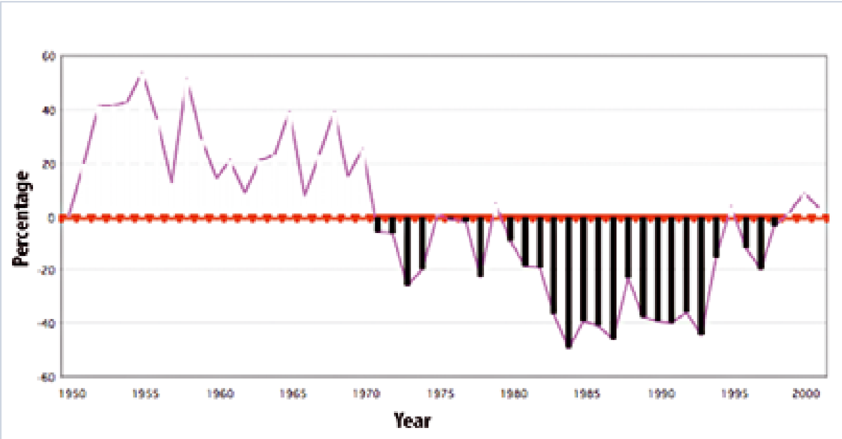


Figure 3.11: The Niger River's annual discharge in Niamey: for the period 1950-2001 (Source: Niasse et al. 2004)

5.4 Cameroon-Nigeria on Lake Chad: Maintaining contact with receding waters

In recent years, a water dispute occurred between Cameroon and Nigeria on the southern part of the Lake Chad, in particular the village Darak and surrounding settlements. Darak – located in Cameroonian territory, 35 km East of the border with Nigeria – was been founded in 1987 by Nigerian fishermen who had immigrated in their pursuit of the progessively retreating Lake Chad – a retreat resulting from consecutive years of rainfall deficits marked by significant decreases in inflows to the lake. The maximum flooded area of Lake Chad decreased from 37,000 km2 in the early 1950s to 15,000 km2 in the early 1990s while the areas flooded for 4 consecutive months shrunk from 23,000 km2 to only 2,000 km2 during the same

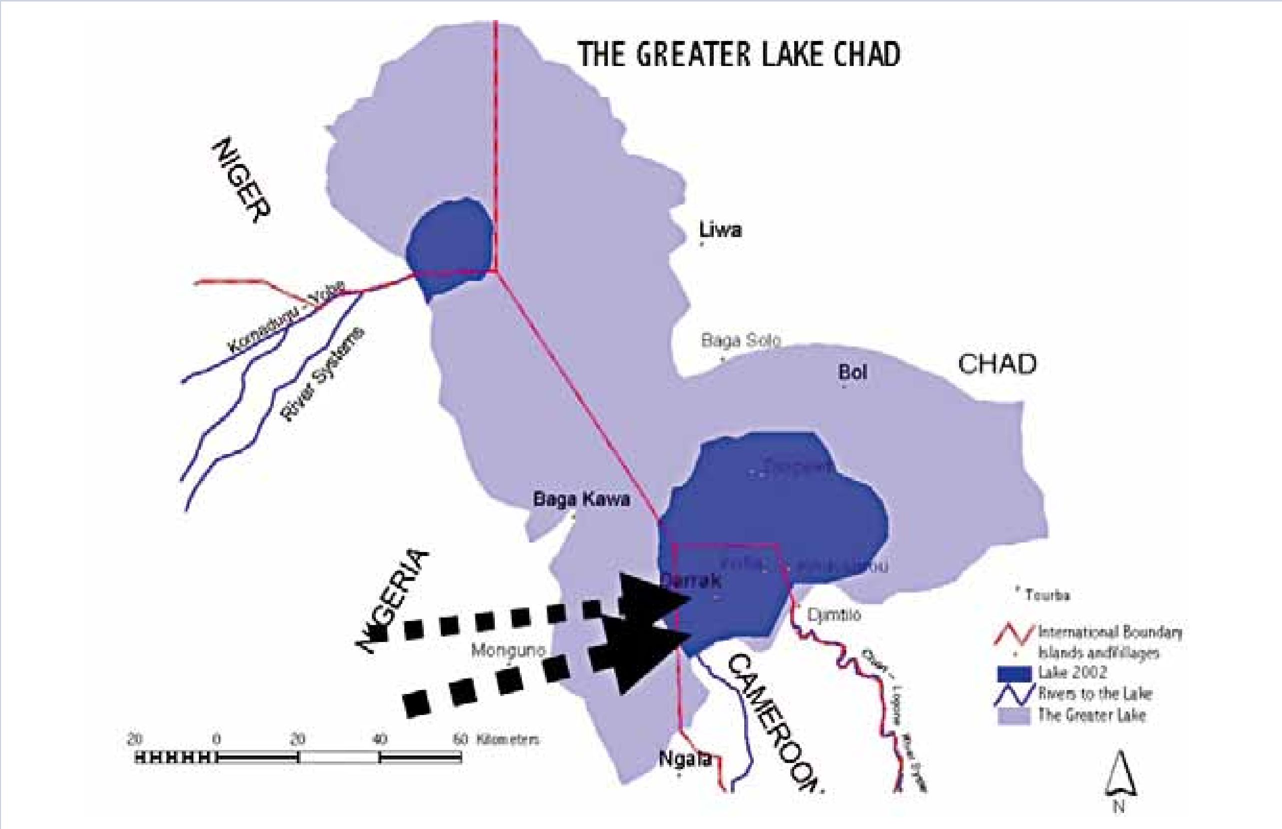
[7] NBA. 2002. See Annex 7 in particular: „Position du Nigeria sur les projets de barrages de Taoussa (Mali) and Kandadji (Niger)"

period. In the mid-1990s, more than 30 villages populated by Nigerian immigrants (with a total population of 70,000 inhabitants) were identified in the Cameroonian part of the Lake Chad Basin (IRIN News, 2003a).

The tension between Cameroon and Nigeria grew owing to the fact that Nigeria followed its citizens' movement by deploying in Nigerian dominated villages its state control and its public service functions: For example, armed forces (military and police forces), establishment of Nigerian schools and health centres, etc.. In addition, these villages were integrated in Nigeria's decentralised administration of its territory and became part of the Nigerian District of Wulgo, in the Local Government Unit (LGU) of Ngala in Borno State[8]. After a series of military skirmishes in the 1980s and 1990s, the two countries tried without success to solve the problem in the context of the Lake Chad Basin Commission (LCBC) to which they are both members. In 1994, they decided to seek arbitration at the International Court of Justice (ICJ), by adding the matter to the general border dispute[9] between the two countries that was then pending before the ICJ.[10] Following the ICJ arbitration in favour of Cameroon (October 2002), Nigeria started in December 2003, to withdraw from the disputed territory (IRIN, 2003b).

As the above illustrative cases show, risks of water conflicts are high and increasing in West Africa. It is fortunate that none of these cases have so far resulted in open armed confrontation; but one wonders how long devastating conflicts can be avoided. If nothing is done to address the issue, and if climate impacts on water get worse as it is predicted in most scenarios, the risks of perturbation of the peaceful relations between countries sharing the same watercourses could be seriously affected.

Figure 3.12: Migration of Nigerian fishermen to the Cameroonian part of Lake Chad (Base map from LCBC Remote Sensing Unit. May 2002)



[8] International Court of Justice: http://212.153.43.18/cijwww/cdocket/ccn/ccnframe.htm

[9] The most known part of this dispute relates to the Bakassi Island

[10] Le Messager No.1425 daté Oct 11, 2002 Entrevue de Douala Moutomè: Nous sommes allés à la Haye avec la certitude que c'est là que viendrait la solution. Source :www.wagne.net/messager/messager/1425/messager.html

5.5 Common patterns of conflicts risks in West Africa

The major features of the conflict risk described can be summarised as follows:

Climate change and climate variability lead to incresaing water scarcity. In trying to cope with the changing context, communities devise adaptation strategies in order to maintain access to water and to those esources they derive from it. These strategies sometimes ignore the new political context, and in particular the boundaries of modern States. That is for example the case of Nigerian villagers following Lake Chad in its retreat out of Nigerian territory.

The changing climate context can also lead States and basin organisations to develop water control infrastructures such as irrigation schemes, diversion channels or dams. In these instances, the new water infrastructures while benefiting some sections of the basins often penalise other sections. Territories perceived as benefiting from new infrastructures became then highly disputed. If they are located in border zones, each of the riparian States seek to affirm their sovereignty on these territories. "Fuzzy borders" became therefore zones of protracted dispute (case between Senegal and Mauritania). In some cases the very prospect of developing water control infrastructures triggers anticipatory reactions similar to the ones observed after these investments are made (case of Niger and Benin over the Lete Islands).

The sharing of the costs (negative impacts) of water development infrastructure is also often at the root of many interstate disputes. One of these adverse impacts is the alteration of the river regime, translating into amplified flood levels or reduction of downstream river discharge. Devastating floods that have recently occurred in the Ghananian part of the White Volta have been allegedly linked to the operations of Burkina Faso's Bagre Dam. Similarly, reduced inflows to the Akosombo reservoir is perceived by public opinion in Ghana as being caused by increased level of dam construction in Burkina Faso. Policy makers in Nigeria have in the same vain expressed fears that the Kandadji and Tossaye Dams in the Niger and Mali portions of the Niger River would result in significant decreases of water inflows to the Nigerian sections of the Niger River.

It is clear that ignorance of the real impacts of climate change and variability is a common reason of many of the tensions over shared waters in West Africa in recent years. States tend to blame their neighbours for problems that in many cases are caused by changing climate conditions.

6. Measures for preventing conflicts risks and for promoting cooperation over shared waters

In anticipation of the persistence or aggravation of current climate conditions and their impacts on West African freshwater resources, there is need to set in place effective mechanisms for preventing and managing conflicts that could arise between water users, especially between riparian States. Based on the causes of the conflicts described earlier, the following measures could help reduce the region's vulnerability to climate-induced water conflicts:

i. Increase awareness on the impacts of climate variability and change on water resources. Despite the significance of climate impacts on West African water resources, there is still a very low awareness on climate change and variability amongst not only the general public but also among policy makers and opinion leaders.

ii. Encourage international and basin-level collaboration on climatic and hydrologic data collection, management and sharing. The cases of the tensions between Ghana and Burkina Faso and between Nigeria and Niger show how critical a shared knowledge on climate change impacts on transboundary rivers is. Up to now, data collection and management efforts have been undertaken at national levels, which results in fragmented information at the levels of transboundary waters.

iii. Establish and/or strengthen collaboration mechanisms at the levels of river basins. Even if the sharing of information is done in an effective manner, conflict risks will remain, and it is therefore necessary to provide the region with strong mechanisms for managing these conflicts. Existing River Basin Organisations — the Senegal River Basin Development Authority (OMVS); Niger Basin Authority (NBA); the Lake Chad Basin Commission (LCBC), the Gambia River Development Authority (OMVG) – need to be strengthened, especially in their regulatory roles. Similarly, bilateral agreements on shared waters – for example the Niger-Nigeria Joint Committee on water; the Memorandum of Understanding between Cameroon and Nigeria on the Benoue River; the agreements between Benin and Niger or between Niger and Mali or between OMVS and Guinea – could provide effective means of collaboration for prevention risks of water conflicts[11]. Many of these agreements are however only on paper and need to be translated in actual cooperation. In cases like the Volta River Basin, there is an urgent need to establish a basin-level regulatory structure and to establish formal consultation and collaboration mechanisms at bilateral levels, for example between Ghana and Burkina Faso.

iv. Promote the adoption of emerging principles of international law on transboundary watercourses, especially the 1966 Helsinki Rules and the 1997 United Nations Draft Framework Convention on Non-Navigable Uses of Transboundary Watercourses. The set of principles spelled out in these laws can be used to formulate consensus codes of conduct at river basin levels and a water protocol at the regional level.

v. Promote the adoption of the emerging standards regarding the planning and management of dams, especially in cases where transboundary rivers are targeted[12].

vi. Promote water saving techniques and water demand management in order to decrease the currently growing pressure on the region's freshwater resources.

7. Conclusion

With the persisting degradation of the climate and the predicted worsening of the situation in the coming years, the risks of conflicts over water will increase; especially in regions such as West Africa which are composed of highly interdependent countries. A number of cases of serious risks of conflict have already been noted in many parts of West Africa. International tensions can allow for a distortion of the apparent causes of decreased water availability and/or altered water quality; upstream countries invariably being blamed for phenomena that are in reality caused by climate change and variability. In this context, the most urgent conflict prevention measures are to increase awareness on climate impacts, and to promote collaboration in hydrologic and meteorological data collection, analysis and sharing. Given that the risks of conflicts can be minimised but not avoided, it is also important to strengthen mechanisms of dialogue and collaboration on water and climate. These mechanisms include river basin organisations and bilateral agreements on water. It is also important to encourage West African countries to develop codes of conduct for managing shared waters on the basis of the emerging principles of international law. As dams are in most cases the triggers of conflicts, efforts should be made to adopt the emerging international standards regarding their planning and management, especially when transboundary rivers are targeted. At the same time, it is important to promote water saving techniques and water demand management in order to decrease the exponentially growing water demand, and so reduce the pressure on the region's freshwater resources.

[11] For a more detailed analysis of river basin organisation models in West Africa and bilateral agreements on shared waters see: Niasse, M. 2004.

[12] On these standards, see WCD. 2000; and Niasse, M. 2004b.

References cited

ANDAH, W. E.I. 2003. Climate Variability/Change and the Energy Crises in Ghana. Input to the West Africa Adaptation Strategy on Water and Climate. IUCN-BRAO. May

ANDREINI, M; N. van de GIESEN, et. al. 2000. Volta Basin Water Balance. Center for Development Research. University of Bonn. ZEF Discussion Papers. No. 21. March 2000

Ashton, P. J. 2002. Avoiding Conflicts over Africa's Water Resources. Ambio. Vol 31 No.3, May. Pp236-242

Critchley, W.H. and Terriff, T. (1993) Environment and Security. In Security Studies for the 1990's eds. R. Shultz, R. Godson, and T. Greenwood. Brassey's, Washington D.C

GWP-WATAC. 2000. Water for the 21st Century. Vision to Action for West Africa. Global Water Partnership-West Africa Technical Advisory Committee (GWP-WATAC). Ouagadougou.

GORDON, C. & J. K. AMATEKPOR (eds). 1999. The Sustainable Integrated Development of the Volta Basin in Ghana. Volta Basin Research Project. University of Ghana – Legon. Accra

Hollis, G.E. 1990. Senegal River Basin Monitoring Activity: Hydrological Issues. Part. I. IDA Working Paper No.56. Binghamton (NY).

Hollis, G.E.; Adams, W.M & Aminu-Kano, M. 1993. The Hadedia-Nguru Wetlands. Environment, Economy and Sustainable Development of a Sahelian Floodplain Wetland. IUCN, Gland.

Homer-Dixon, T. F. (1991). On the threshold: Environmental changes as causes of acute conflict, Int. Security, 16, 76– 116.

Horowitz, M.M. 1989. Victims of Development. Development Anthropology Network. 7(2):1-8

ICJ. No date. Land and Maritime Boundary Between Cameroon and Nigeria. International Court of Justice (ICJ): www.icj-cij.org/icjwww/idocket/icn/icnframe.htm

IRIN News.2003a.Cameroon-Nigeria: Border Commission discusses handover of 33 villages. Integrated Regional Information Networks(IRIN): www.irinnews.org/report.asp?ReportID=37536&SelectRegion=West_Africa). Oct. 29. Abuja

IRIN News. 2003b: Cameroon-Nigeria: Handover of Lake Chad villages begins. Integrated Regional Information Networks (IRIN): www.irinnews.org/report.asp?ReportID=38319&SelectRegion=West_Africa) Dec. 9. Lagos

Lipschutz, R. D. (1989), When Nations Clash: Raw Materials, Ideology and Foreign Policy, Ballinger, Cambridge, Mass.

Magistro, J., V. Crossing Over. Ethnicity and Transboundary Conflict in the Senegal River Valley. Cahier d'Etudes Africaines. Vol.130 XXXIII-2 pp.201-232

NBA. 2002. Réunion d'information sur les barrages de Taoussa (Mali) et de Kandadji (Niger). Niamey 6-7 août. Autorité du Bassin du Niger (Niger Basin Authority). Niamey.

NIASSE, M.. 2002. Equity Dimensions of Dams-Based Water Resources Development - Winners and Losers. In Steffen, Will; Jäger, J.; Carlson, D.J.; Bradshaw, C. Challenges of a Changing Earth. Springer. Berlin, London. Chap.6 pp.39-43

NIASSE, M.. 2004. Prévenir les conflits et promouvoir la coopération dans la gestion des fleuves transfrontaliers en Afrique de l'Ouest. In VertigO (Environmental Sciences Electronic Journal). Vol 5 (1). May http://www.vertigo.uqam.ca/vol5no1/art5vol5no1/vertigovol5no1_niasse.pdf

NIASSE, M.. 2004b. La construction de barrages sur les cours d'eau partagés: recommendations de la Commission mondiale des barrages (CMB) in Niasse, M; Iza, A. ; Garane, A. ; Varis, O. 2004. La gouvernance de l'eau en Afrique de l'Ouest (eds). UICN. Droit et politique de l'environnement, No.50. IUCN, Gland (Switzerland) & Cambridge (UK). Pp. 71-76

NIASSE; M.. 2006. Transboundary River Basins in Atlas on Regional Integration in West Africa. ECOWAS-SWAC/OECD. Paris. Aug. 2006).. Web: http://www.oecd.org/dataoecd/41/45/38409569.pdf ;

NIASSE, M. ; AFOUDA, A. ; AMANI, A.(eds). 2004. Reducing West Africa's Vulnerability to Climate Impacts on Water Resources, Wetlands and Desertification. Elements for a Regional Strategy for Preparedness and Adaptation. IUCN, Gland (Switzerland) & Cambridge (UK)

Oyebande, L.; Amani, A.; Mahé, G. and Diop, I. N.. 2002. Climate Change, Water and Wetlands in West Africa: Building linkages for their Integrated Management. Working Paper. IUCN-BRAO. Ouagadougou. April;

Parker, Ron. 1991. The Senegal-Mauritania Conflict of 1989: A Fragile Equilibrium. Journal of Modern African Studies, 29-1, pp155-171

Postel, S. L. Postel and Wolf, A.T.. 2001. Dehydrating Conflict. Foreign Policy. Sep.18 http://www.globalpolicy.org/security/natres/water/2001/1001fpol.htm

Seck, S.M, 1991. Les cultivateurs "transfrontaliers" de décrue face à la question foncière. In Bernard Crousse, Paul Mathieu, Sidy M. Seck (1991). La Vallée du Feuve Sénégal. Evaluations et perspectives d'une décennie d'aménagements. Paris. Karthala

Turton, A. R; 2000. Water wars in Southern Africa: Challenging conventional wisdom. In Water for Peace in the Middle East and Southern Africa. Green Cross International. Genève. Pp 112-130

Van de GIESEN, N.; M. ANDREINI, A. van EDIG & P. VLEG. 2001. Competition for Water Resources of the Volta Basin. Center for Devlopment Research. University of Bonn.

WCD. 2000. Dams and Development. A New Framework for Decision Making. The Report of the World Commission on Dams. Earthscan. London

Wolf, A. 2001.. Water, Conflict, and Cooperation. In Ruth S. Meinzen-Dick and Mark W. Rosegrant (eds): Overcoming Water Scarcity and Quality Constraints. 2020 Focus 9: October. Source: http://www.ifpri.org/2020/focus/focus09/focus09_14.htm

Wolf, A.T.; Yoffe, S.B.; and Giordano, M. 2003. International Waters: Identifying Basins at Risk. Water Policy No. 5 pp29-60

Yoffe, S.; Wolf, A.T.; Giordano, M. 2003. 'Conflict and Cooperation over International Freshwater Resources: Indicators of Basins at Risk', Journal of the American Water Resources Association, Vol. 39, No. 5, pp. 1109–1126.

Chapter 4

Challenges to Managing Floods and Droughts in Transboundary River Basins in Mozambique

By Boaventura Chongo Cuamba and Genito Amós Maúre. Eduardo Mondlane University. Maputo, Mozambique

Contents

Figures

Tables

1. Abstract

According to IPCC Fourth Assessment Report, warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations.

Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century. So far the focus of the international community as far as climate change is concerned, has been on mitigating climate change by reducing greenhouse gas emissions. Yet for many poor communities in poor countries, mitigation is not the most pressing issue. Climate change is already having an impact on these communities, and what they now need is ways to adapt to it. Mozambique, due to its geographic location, is very vulnerable to climate change impacts, namely floods and droughts; therefore, the development of adaptation capabilities to deal with climate change impacts is of paramount importance. 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 made worse 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. Both floods and droughts occur mainly in the transboundary rivers basins. Mozambique is very vulnerable to both phenomena, due to the weak national socio-economic infrastructure and extreme poverty of the populations. In Mozambique, around 10 million people live in absolute poverty. Thus, it is both important and urgent to build adaptive capacity in order to help the country to resist to climate change issues. Adaptation strategies, if they are to be effective, should be discussed at international, regional, national and local levels. In each of these levels it is necessary to outline appropriate measures. At international level support is necessary for developing countries to cope with the challenges of adaptation to the changing climate. Mozambique is located downstream of the major transboundary rivers basins, and it is in the areas of such basins that both floods and droughts occur with higher intensities. Both calamities are driven by natural phenomena of availability or no availability of rain and also by inefficient management of dams. Therefore, regional agreements for water sharing are essential. At national and local levels the mainstreaming of climate change into development programmes and the building of resilience are very important.

2. Introduction

According to Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level [1]. Observational evidences from all continents and most oceans show that many natural systems are being affected by regional climate changes, particularly temperature increases. Global green house gases (GHG) emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. Global atmospheric concentrations of CO2, methane (CH4) and nitrous oxide (N2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values as determined from ice cores spanning many thousands of years. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations. It is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica). There is high agreement, and much evidence, that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.

So far the focus of the international community as far as climate change is concerned, has been on mitigating climate change by reducing greenhouse gas emissions. Yet for many poor communities in poor countries, mitigation is not the most pressing issue. Climate change is already having an impact on these communities, and what they now need is ways to adapt to it [2]. The early studies into the impacts of climate change used global circulation models in a top-down manner to predict scenarios in different places. Based on these results, the next phase of research used a more bottom-up approach to identify the places, activities and communities most at risk. These in turn led to a third generation of studies that use both sets of information to develop plans for how those affected can best prepare and adapt. None of these studies has yet progressed beyond carrying out theoretical analysis. The next generation of research must be linked actively to the people whose lives will be affected, and researchers must learn from doing. They must work with the people who will use their research, right the way through from designing a project to implementing it and communicating its findings. Such users will include national policy makers and planners responsible for adaptation matters. They will also include local governments, aid workers and non-governmental organisations who are working on adaptation at the community level.

Mozambique, due to its geographic location is very vulnerable to climate change impacts. Therefore the development of adaptation capabilities to deal with climate changes impacts in Mozambique is of paramount importance. This paper presents a review of the situation of the country regarding floods and droughts, and outlines the major measures to help the country to adapt to both climate change phenomena.

Figure 4.01: Flood damages to settlements and infrastructure

3. Geography, Morphology, Geology and Climate of Mozambique

Mozambique is located on the south-eastern Indian Ocean coast of Africa, bordering on the Republic of Tanzania in the north, on Malawi, Zambia and Zimbabwe in the west, and on Swaziland and The Republic of South-Africa in the south. It is located between latitudes 10 and 27 degrees south and between longitudes 30 and 41 degrees east. The country's surface area is 799,380km^2, with a coastline of about 2,800km. Mozambique is divided into ten provinces, each with a capital city, being Maputo the national capital, with the administrative status of a province. The 10 provinces (excluding Maputo City) are subdivided into 129 districts. Districts are further divided in administrative posts and these into localities which is the lowest geographical level of state administration. For certain purposes it is also to consider three regions in the country, namely the northern, central and southern regions. The northern region comprises the provinces of Cabo Delgado, Niassa and Nampula, the central region comprises of the provinces of Zambézia, Tete, Manica and Sofala, and the southern region encompasses the provinces of Inhambane, Gaza and Maputo. See Figure 4.1 for the geographic position of the country and administrative division. According to the preliminary results of 2007 Census, the total population of Mozambique is 20,530,714, with more than one million people living in the capital city, Maputo. Approximately 65.5% [3] of the population is living in rural areas grouped in small communities spread all over the country.

Figure 4.1: Geographic position and administrative division of the country

Mozambican physical geography is characterised by low-lying flat areas in the coastal regions, with an increase in altitude, as one move towards the interior and the north of the country, and a succession of plains, plateaus and mountains [3]. The average altitude is 370 metres. There is a clear distinction between the region south of the Save river, with an average altitude of only 120 metres, and the region north of the Save with an average altitude of 435 metres. The highest areas (the mountainous area of Manica, Upper Zambézia, and the Angónia, Marávia, and Lichinga plateaux) are also the areas of greatest rainfall. The topographic map of the country (Figure 4.2) shows predominant hilly areas with topographic elevations above 1,500m in the north-western parts of the country, whereas the southern regions consist predominantly of lowlands of less than 100m elevation.

The country can be divided into four main land zones:

- From the coast to the interior, the plains lie at an elevation of less than 200m and cover more than 40% of the land area. North of the Zambezi River, the plains are between 60km and 100km wide. In the Zambezi Valley the plains extend upstream about 600km south of the Zambezi River the plains are up to 100km wide. The coastal area is divided into different sections. The northern part is composed of craggy coasts. In the Zambezi Delta and in the southern area, beaches interrupt mangroves.
- The lower and middle plateau, covering about 30% of the land area, extends from the plains in the west (elevation 200m to 500m). The biggest area is located in the north of the country.
- The middle plateau (elevation 500m to 1,000m) covers approximately 26% of the land area and is located in the western part of northern and middle Mozambique.
- The remaining area is mountainous (with elevations above 1,000m) and accounts for about 5% of the land area. The mountains of Alto Niassa, Alta Zambézia and Angónia are of importance. The highest point in Mozambique is Monte Binga with 2,436 m.

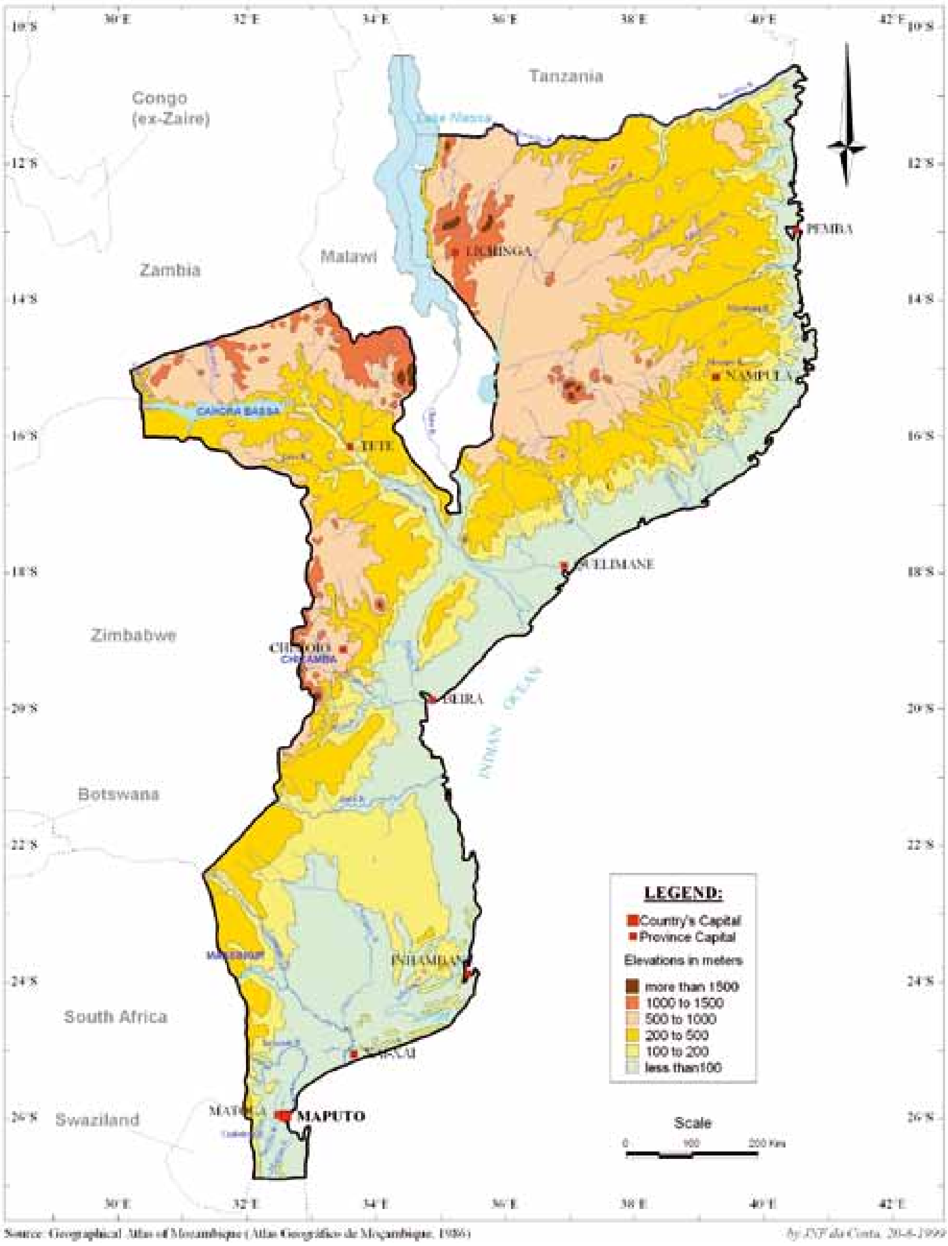


Figure 4.2: Topography of Mozambique

In geological terms, four main formations can be distinguished:

- Quaternary sedimentary formations, which cover practically the entire region south of the Save river, the coastal areas of Sofala and Nampula provinces, the low-lying area of the Zambezi Valley, and the area of Cabo Delgado province east of the plateau between Macomia and Mueda;
- Metamorphic rocks of the Primary and Pre Cambrian, corresponding to the plateaux and part of the mountainous areas, and covering almost completely Cabo Delgado, Niassa, Tete, Nampula, and Manica provinces, and the interior of regions of Zambézia, and Sofala provinces;
- Eruptive rocks of the Primary and Pre Cambrian Palaeozoic, the Secondary Mesozoic, the Tertiary and Karoo, corresponding to the greater part of the mountainous areas, and the interior zones of the Tete, Manica, Gaza and Maputo provinces;
- Sedimentary Karoo rocks, occurring only in Niassa and Tete provinces.

Since it is located between the intertropical and subtropical zones of the Southern Hemisphere, the country is subject to four main factors of atmospheric circulation:

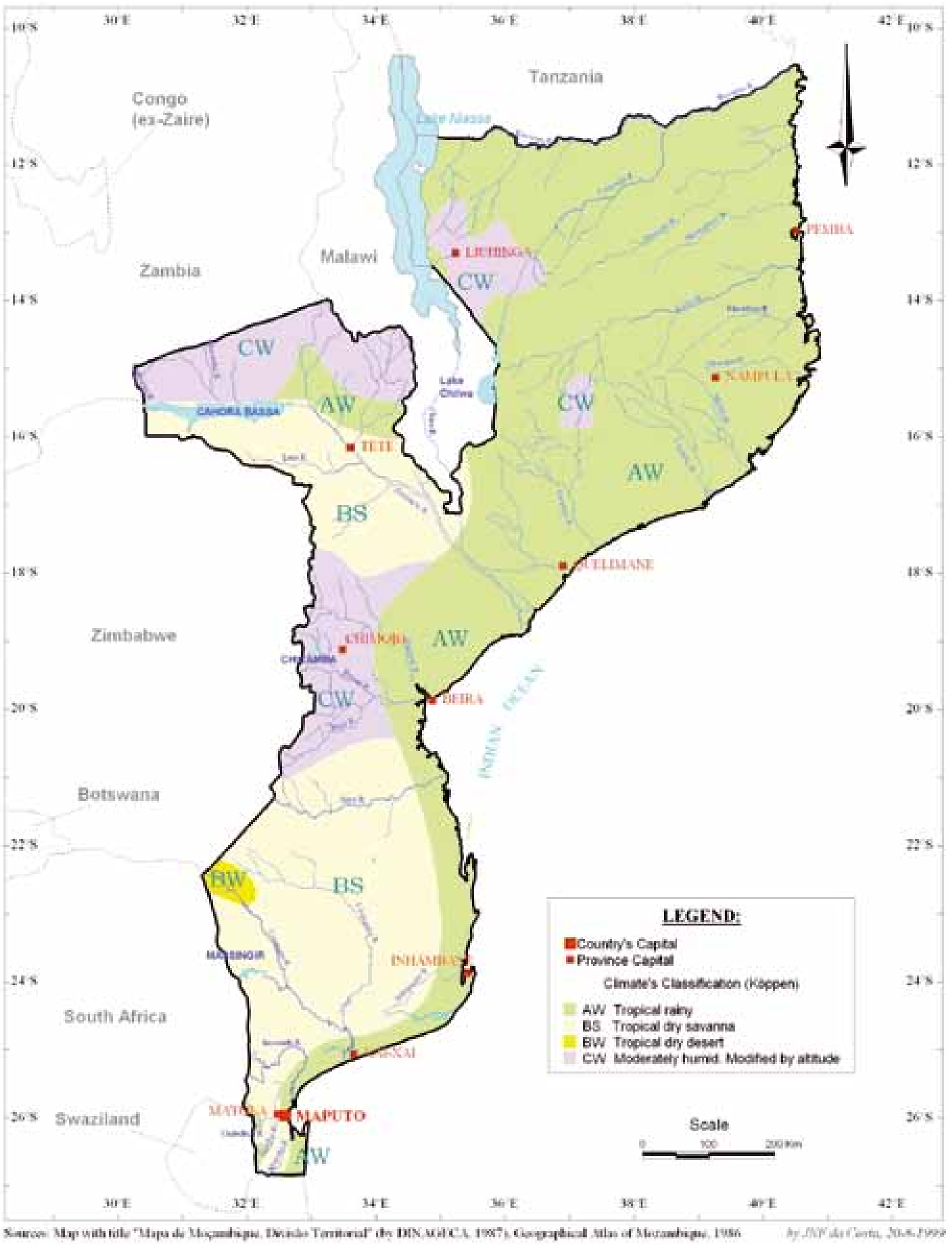


Figure 4.3: Types of climate in Mozambique (Köppen's classification)

- The position of the Southern Intertropical Front (SIF);
- Anti-cyclones of the South Atlantic and Indian Oceans;
- Depressions of thermal origin during the hot season;
- Tropical cyclones over the Mozambique Channel.

The country can be divided into four climatic regions, according to Köppen (see Figure 4.3).

- The northern and coastal regions, representing 60% of the total area of the country, have a tropical rain savanna climate (AW).
- The inland parts of the central and southern sedimentary terrains, representing 28% of the country, have a dry savannah climate (BS); this happens in most of the area south of the Save, and in Tete province, south of the Zambezi river.
- A small area around the border crossing of the Limpopo River (2%), in Gaza province, has a dry desert climate (BW).
- The upland areas (10%) have a humid temperate climate (CW); this happens in Gurué, Manica, Angónia and Lichinga.

In the south of the country, the mean temperature varies between 23 degrees centigrade in the coastal areas and 25 degrees in the interior, where the climate is drier. In the north, temperatures are in general higher, with an annual mean of 25-26 degrees 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 Norwest, located at 1,200 metres above the sea level, where the mean annual temperature is 18 degrees. In the central region of the country, the mean annual temperature is 25 degrees, but in upland areas it falls to 20 degrees. 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 1,000 mm. South of Pemba there is a reduction to below 800 mm, and between Beira and Quelimane, the figure is higher than 1,200 mm. 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 2,000 mm, except in the region between Tete and Chemba, where just 500 to 600 mm of rainfall occurs in average annually. 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.

4. An Overview of Water Resources

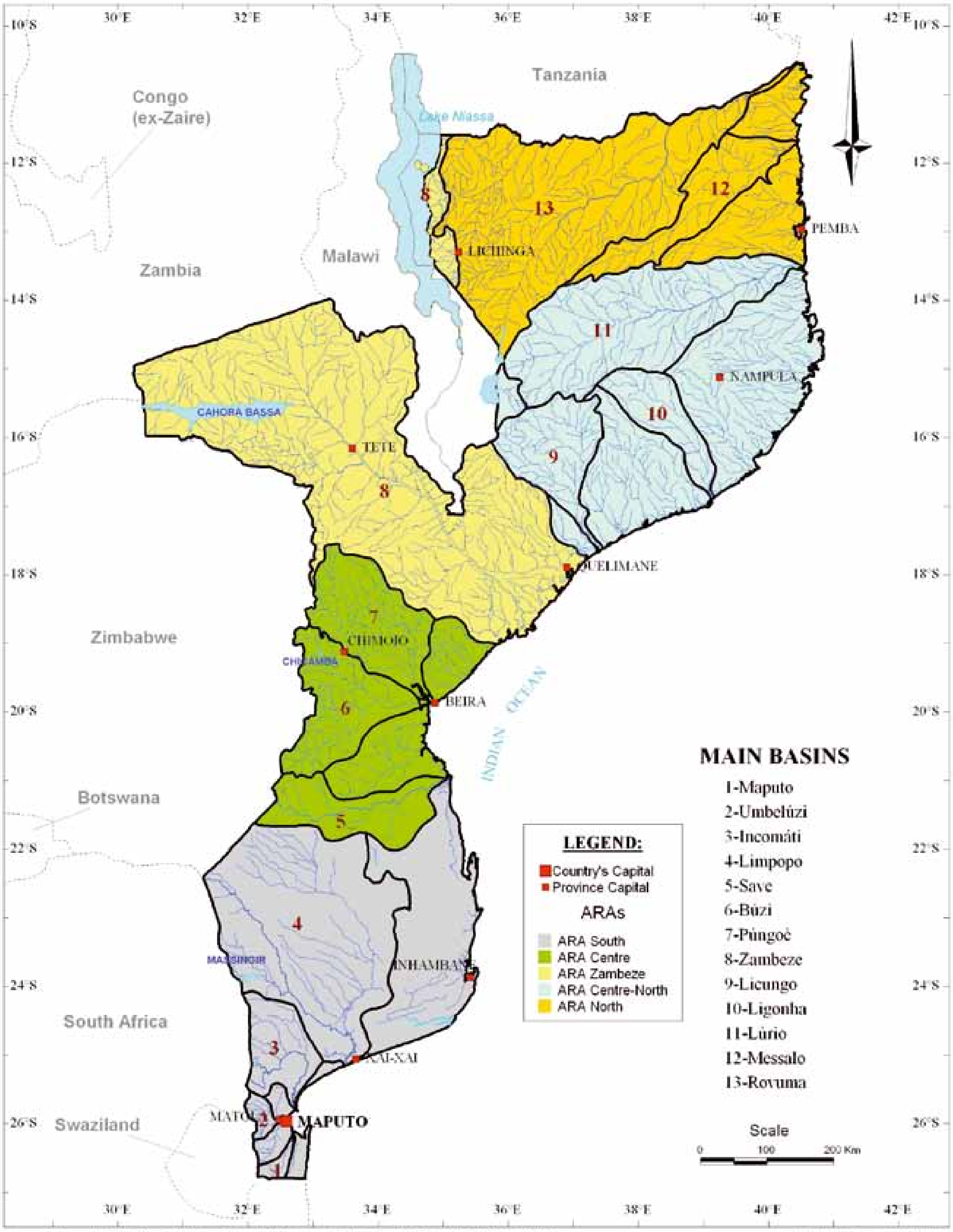
The demand for water in Mozambique is divided between urban supply, supply for the rural population, irrigation, hydropower production, industry and mines, forestry and conservation of the environment. In Mozambique, irrigation is the major consumer of water, followed by urban water supply, industry, and rural water supply [3]. In the next sections a review of both surface and ground water resources will be considered.

4.1 Surface waters

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 identified river basins, considering only the rivers that flow into the Indian Ocean. The coastal area is regarded as a single basin.

With the exception of small rivers that drain in 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, in accordance with the rainy and dry seasons. 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 characterised by reduced runoff coefficients, heavy intrusions of salt water at the river mouths (reaching more than 50 kilometres 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 rivers basin in the centre. The rivers rise in the mountainous border areas and descend gradually to the sea, where there is also heavy salt-water intrusion. These rivers have a more permanent runoff regime when 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.



Sources: Map with title "Bacias Hidrográficas" (by Serviços Hidráulicos, 1976), DGRH/DNA, 1998 — by JNF da Costa, 20-8-1999

Figure 4.4: Rivers basins of Mozambique

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. 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 plateaux and the mountains. Some of the rivers have important waterfalls and steep slopes, with good hydropower potential. The Lurio, Licungo, Messalo, and Ligonha rivers stand out. The Rovuma River makes the border with Tanzania.

Figure 4.4 shows rivers basins of Mozambique and Figure 4.5 the international rivers basins of Mozambique.

The surface waters are the country's main water resource. Mean annual runoff is estimated at 216,000 million cubic metres (Mm^3), of which only 100,000 Mm^3 originated in rainfall inside Mozambique. The remainder originates in countries upstream, which is why this figure has been 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 5,556 cubic metres/inhabitant/year, taking into account only the runoff generated in the country, or 12,000 cubic metres/inhabitant/year, including the flows from neighboring countries. Both these figures, howe-

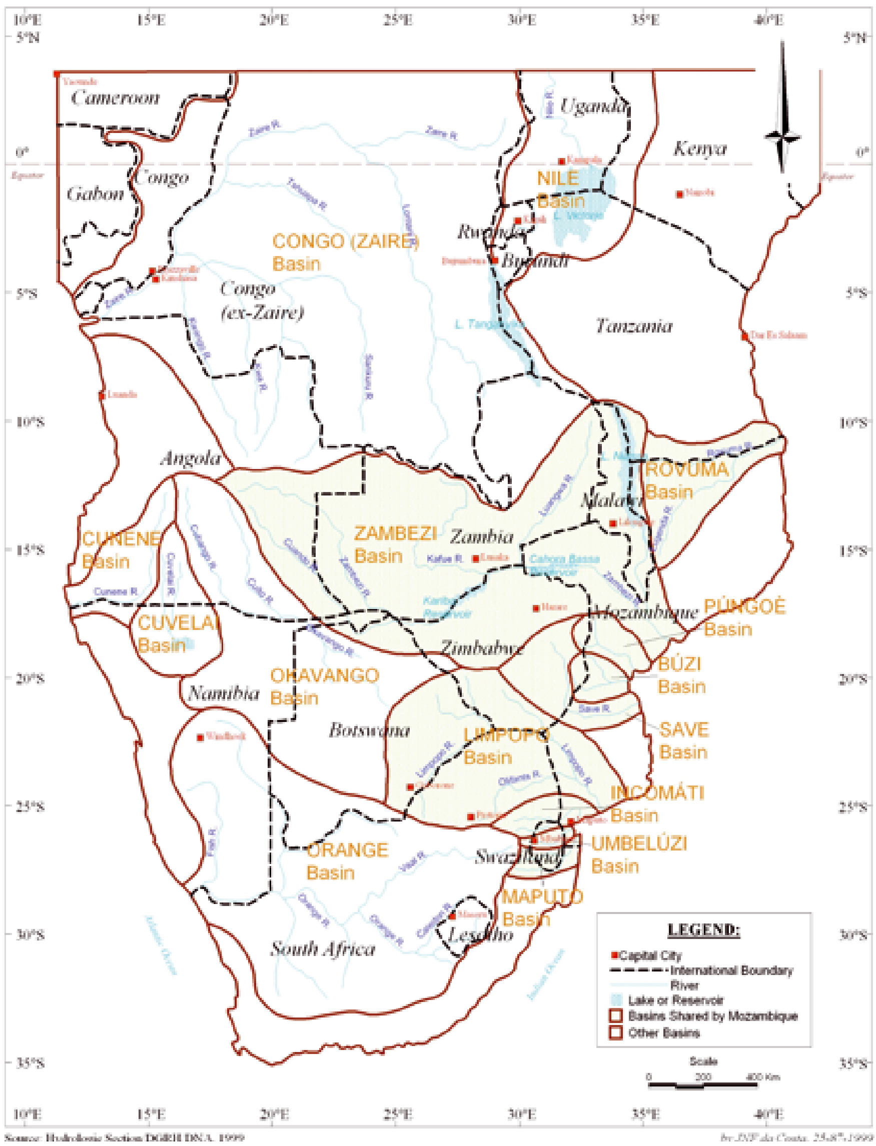


Figure 4.5: International Rivers Basins of Mozambique

ver, are constantly declining, on the one hand due to population growth, and on the other, because of the reduction in the flows from countries upstream. Table 4.1 represents per capita availability of surface water.

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.

In terms of geographic distribution, five regions have been identified, bringing together contiguous river basins and they are administered by the Regional Water Administration (ARAs), set up by the Water Law:

- ARA-South: includes all the basins south of the Save, and the Save river basin itself;
- ARA-Centre: Covers all the basins between the Save and the Zambezi basins;
- ARA-Zambezi: Corresponds to the Zambezi river basin;
- ARA-Centre North: Covers the basins north of the Zambezi basin as far as the Lurio river, including the Lurio basin;
- ARA-North: Covers all the basins north of the Lurio basin.

Table 4.2 shows the characteristics of the regions covered by the ARAs, from which one can note that the southern region is entirely dependent on the basins of international rivers.

Region	Population (millions)	Mean annual runoff (km^3)	Per capita water availability (m^3/inhab/year)
Africa	590	4,200	7,119
North America	350	6,000	17,143
South America	260	10,400	40,000
Asia	3,510	13,200	3,761
Australia	20	2,000	100,000
Europe	570	3,100	5,439
World	5,300	38,900	7,340
Mozambique	18	100[a] (216)[b]	5,556[a] (12,000)[b]

a: Considering only the runoff generated in the country
b: Including the flows from neighboring countries

Table 4.1: Per capita availability of surface water, from source [3]

Region	Area *(1,000 km²)*	*Mean annual runoff (km³)*			*Mean annual runoff (km³)*		
		Flow at border	Generated in Mozambique	Total	Flow at border	Generated in Mozambique	Total
South	192	17.0	3.8	20.8	89	20	109
Center	84	1.2	18.4	19.6	14	219	233
Zambezi	140	88.0	18.0	106.0	629	129	758
Centre-North	196	0.0	35.2	35.2	0	180	180
North	168	10.0	24.9	34.9	60	148	208
TOTAL	780	116.2	100.3	216.5	149	129	278

Table 4.2: Characteristics of the regions covered by the ARAS, from source [3]

The growth in demand for water in the countries upstream (South Africa, Zimbabwe, Swaziland) and in Mozambique (supplies for Maputo and for irrigated areas) means that this region deserves priority attention, in order to satisfy the growing demand for water. In the rest of the country, the situation is not such a problem. One should address the Zambezi basin, which accounts for 50% of the country's total surface water resources. This is a region with enormous development potential, particularly for the production of electricity and irrigation of an area of around two million hectares. In terms of distribution over time, the surface water resources of Mozambique, like those of other countries show an annual cyclical variation in rainfall and runoff, in which the dry and rainy seasons are clearly distinguished. In Mozambique the rainy season lasts for a relatively short period. On average about 60-80 % of the annual runoff occurs in just three months. Apart from the annual cyclical variation, in Mozambique, as in all of Southern Africa, there is an important inter-annual fluctuation, with sequences of wet years alternating irregularly with dry years.

4.2 Ground waters

Three hydrogeological formations may 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 with 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 range of action. The hydrogeological conditions of Mozambique make it possible for these systems in virtually the entire country, with some exceptions in the area of the crystalline complex, and some areas where the ground water is at too great depth for the use of hand pumps. This is the case with the interior of the Gaza province, and the far South of Manica province, where the aquifers are at a depth of over 100 metres.

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 contaminations resulting from the discharge of effluents. In a vast area 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

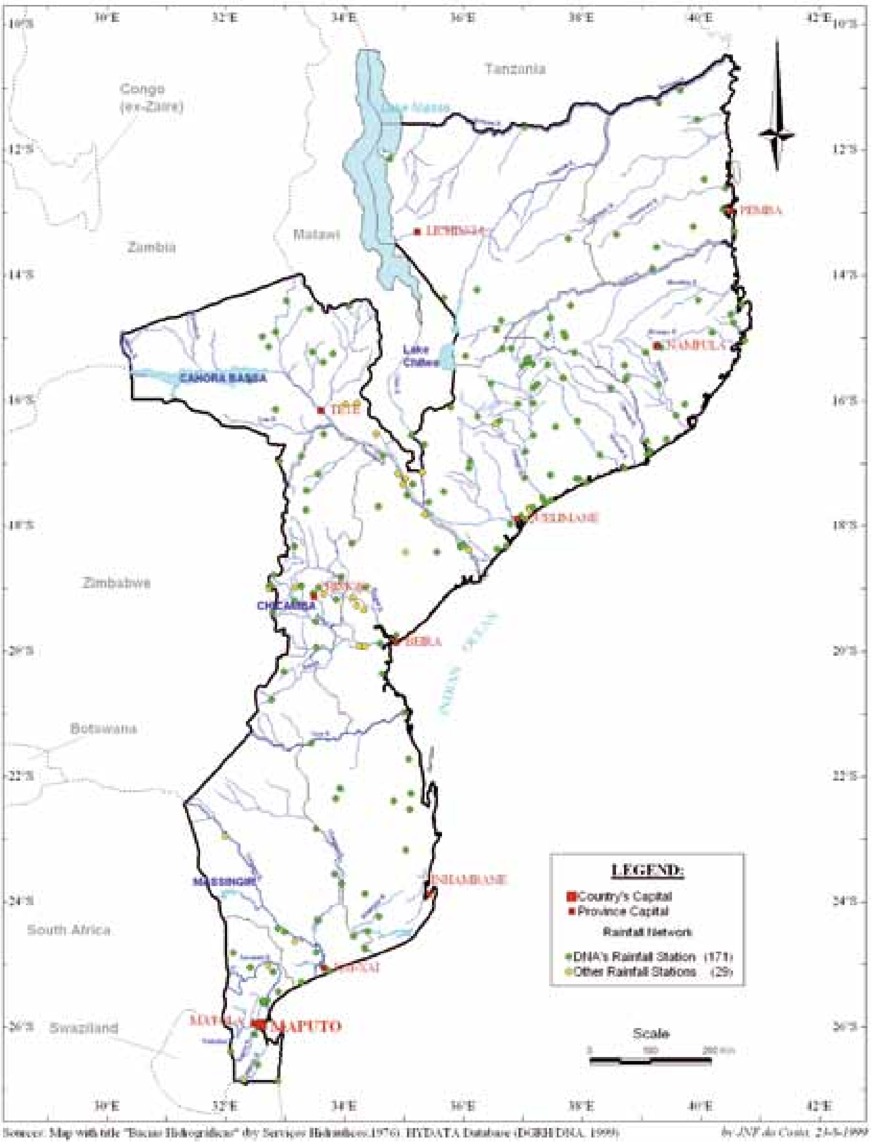


Figure 4.6: Rain gauge network in Mozambique

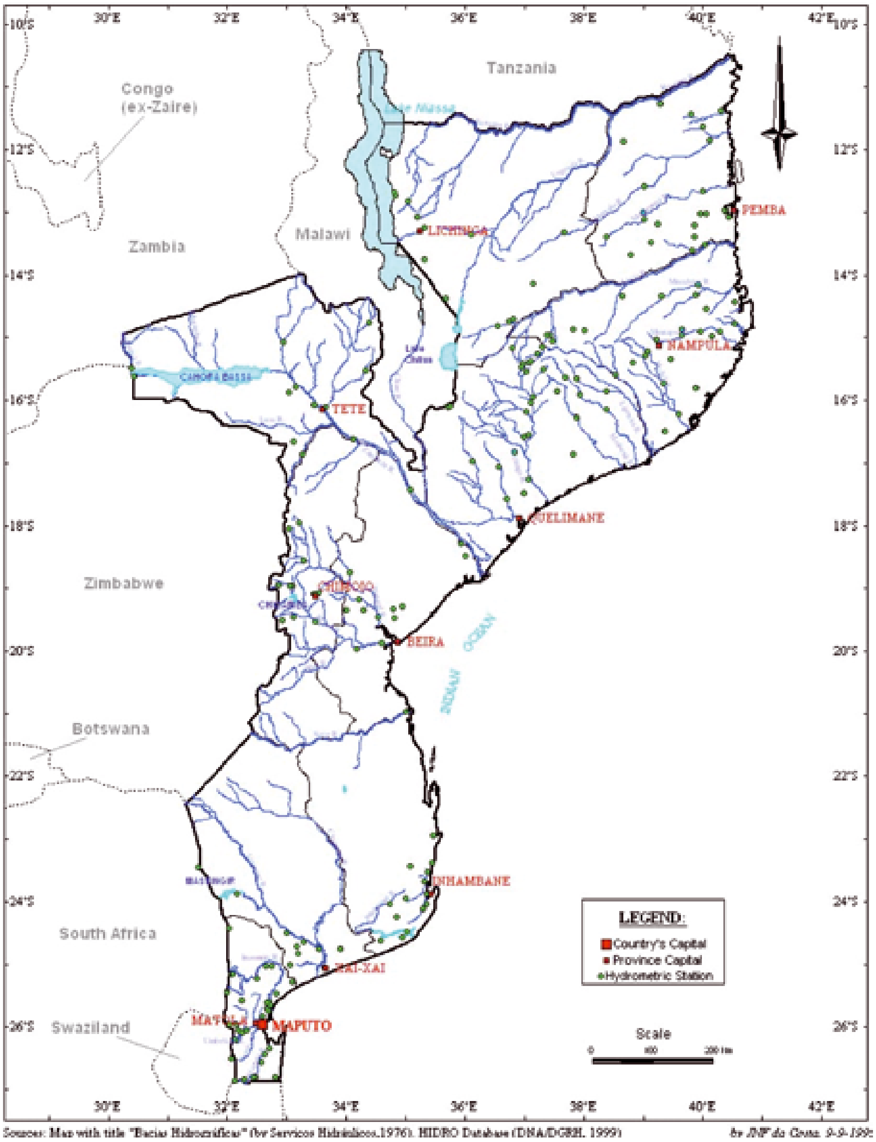


Figure 4.7: Hydrometric network in the country

Hydrometric data are measured by DNA and by the ARAs, and are complimented by measurements made by HCB (Cahora Bassa Hydroelectric Company) and the electricity company, EDM, of the levels and discharges of the Cahora Bassa and Chicamba dams, respectively. The information available from the hydrometric stations is relatively small, since only a small number of stations have data going back 30 or 40 years. Figure 4.7 shows the hydrometric network of the country.

So far there is no network to measure ground water, either in quantitative or in qualitative terms, although this is the water supply source used by some of the country's major cities. Also there is to date no network of stations to control the quality of surface waters. However specific analyses have been undertaken.

4.3 Hydrometeorological networks

The registration, storage and processing of hydrometeorological data are fundamental for the management of water resources. In Mozambique meteorological data are obtained by several institutions – National Meteorology Institute (INAM), Institute for Agricultural Research of Mozambique (IIAM), National Directorate of Waters (DNA), the ARAs (National Water Administrations) and some agricultural companies.

There are a good number of rain gauging stations that possess data going back more than 40 years. The largest series of data refers to Maputo, and includes data from almost 90 years ago. Figure 4.6 shows the rain gauge network in the country.

4.4 Institutional framework of the water sector

In 1991 the Water Law was introduced in Mozambique, incorporating the basic principles and policies of water management [3]. The Water Law stipulates that the main bodies responsible for the management of water resources are the Ministry of Public Works and Housing (MOPH) and the National Directorate of Water (DNA). The Law established the National Water Council, for the inter-sector coordination, and five regional water administrations (ARAs), based on the grouping of contiguous river basins.

In 1995 the National Water Policy (PNA) was approved, defining the strategy to be followed by the water sector, including the integrated management of water resources. The water management institutional framework includes structures at central, regional/provincial and local levels. Centrally, the main institutions directly involved are the NATIONAL Water Council, the Ministry of Public Works and Housing (MOPH) through the National Directorate of Waters (DNA). One should mention the other ministries that intervene centrally, with impacts on water management – the Ministry of Agriculture (MA), the Ministry of

Fisheries (MP), the Ministry of Mineral Resources (MIREM), the Ministry of Health (MS), and the Ministry for Coordination of Environmental Affairs (MICOA). The ARAs are the main institutions at regional level. Other important institutions at regional level are the Provincial Directorates of Public Works and Housing. After the independence there was increasing concern about sharing the international rivers because of the growing retention and use of water by the countries upstream. This led to the creation, in the National Directorate of Waters, of the International Rivers Office (GRI). The main objective of GRI is to establish relations between DNA and the authorities responsible for water resource management in the neighbouring countries.

4.5 Transboundary river basins

There are nine transboundary river basins in the country as outlined in Figure 4.5. The Maputo river (known as Usulu in both South Africa and Swaziland) is shared by the three countries. The Umbeluzi river rises in Swaziland and is shared by Mozambique and Swaziland. The Incomati river has, as its main tributaries, the rivers Sabie (South Africa), Crocodile (South Africa) and Komati (South Africa and Swaziland). The Limpopo river basin covers four countries: Botswana, South Africa, Zimbabwe and Mozambique. The basins of the Save, Buzi and Pungue rivers are shared between Mozambique and Zimbabwe. The Zambezi river is the largest African river that flows into the Indian Ocean, and drains the greater part of the centre4-south region of Africa. The Zambezi basin includes Mozambique and seven other countries: Angola, Botswana, Malawi, Namibia, Tanzania, Zambia and Zimbabwe. Mozambique and Tanzania share the basin of the Rovuma.

4.6 Regional collaboration in transboundary rivers basins

The importance of water resources in Southern Africa, where it is a scarce resource in most of the countries, and where almost all major river basins are shared by two or more countries, ensures that SADC pays a great deal of attention to this matter. This has led to two important developments: the signing of the SADC Protocol on Shared Watercourses Systems and the creation of the SADC Water Sector. The SADC Protocol attempts to fix general principles by which the Member States in each basin should be guided. It seeks to set rules for the establishment of management institutions for these basins and their functions, and norms for solving disputes. On the basis of this Protocol, River Basin Organisations (RBO) has been established with the view of coordinating actions among countries sharing the same basins.

5. Impacts of Climate Change on Hydro Resources

According to the IPCC Fourth Assessment Report [1], 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%.

In the case of Mozambique, work done by INGC [4] showed that the Limpopo river basin is one of the most vulnerable in the country. The Limpopo basin is the second largest of the nine international basins in Mozambique. In addition 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 droughts: a large part of the basin receives less the 500mm precipitation a year.

Another example is a recent work funded by the UNDP and carried out for the Pungwe river basin (Figure 4.4) which shows that dry conditions will get drier; there will be less water available for water supply, irrigation, 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 for 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 adaptation, the works suggests that, in order to avoid very severe consequences, there is a need to prepare now for reduced water availability.

- Take the climate signal into consideration during the planning and decision-making in the communities;
- Strengthen data collection to be able to monitor the weather variations; and
- Cooperate between sectors to make an adaptation strategy and find some important local questions to start with.

Possible changes of the climate until 2050 for the Pungwe river basin, generated by regional climate models are:

- 10% less rain over a year
- A warmer air temperature
- More water lost through evaporation from dams and from the ground
- Delay in the start of the rainy season
- Shorter rainfall season
- Decreased river flow
- Possibly will the very high floods not occur so often
- Higher sea level

6. Impacts of Floods and Droughts

Figure 4.8: An example of the drought effect on soils

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 were 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 infrastructures and caused a very negative impact to the national economy.

6.1 Droughts

The droughts represent very common phenomena in Mozambique, being their impacts worse than those of floods (Figure 4.8). Droughts in the country occur in time frames of 7 to 11 years. The 1991-1992 droughts were the worst in the last years, having affected a large area of Southern Africa. The table below illustrates the occurrence of droughts in Mozambique since the year 1980 (Table 4.3).

On the basis of the measurements undertaken by the National Institute of Meteorology (INAM) data of rainfall from different climatologic stations available in the country have been analysed in order to determine areas of risk to droughts. It is considered that 500 mm of rainfall is the minimum acceptable for some productivity of crops. Figure 4.9 shows areas of vulnerability for droughts based on this analysis.

Year	Description
2002	43 districts affected in the provinces of south and centre of the country.
1999	1,000,000 people affected.
1994-95	1.5 million of people affected in the south and centre of Mozambique, with shortages of potable water, and appearance of cholera diseases.
1991-93	The whole country affected; 1.32 million people affected; failure of agriculture production and shortage of potable water.
1987	8,000 people affected in the Province of Inhambane.
1983-84	The majority of the country affected; appearance of cholera diseases and many deaths due to droughts and war.
1981-83	About 2.46 million people affected in south and centre of the country.
1980	60,000 people affected in the centre and south of the country.

Table 4.3: Occurrence of droughts in Mozambique, from source [6]

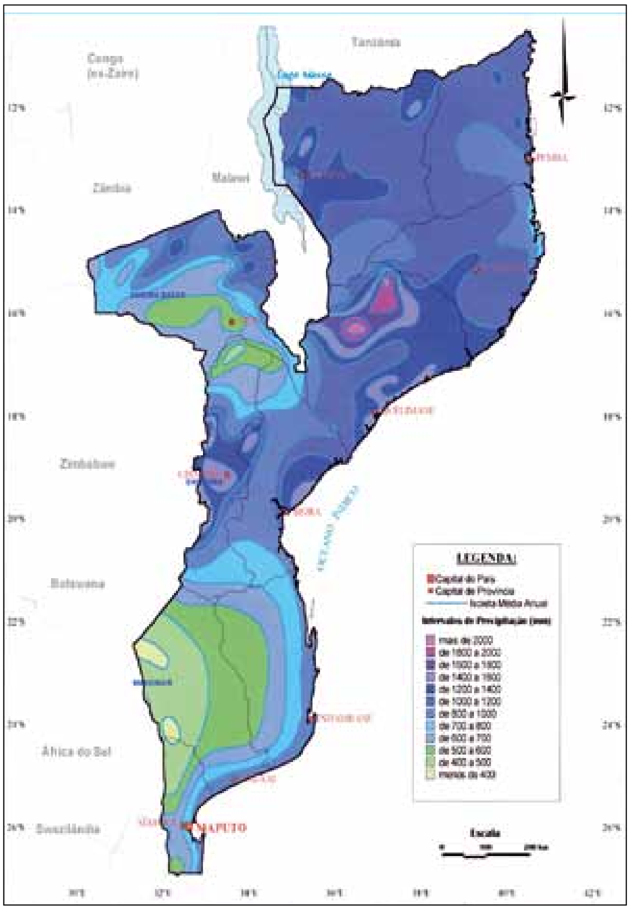


Figure 4.9: Annual average rainfall (mm), from source [6]

6.2 Floods

The country is located downstream of all international rivers crossing the national territory towards the Indian Ocean, like the Rovuma, Zambeze, Pungue, Buzi, Save, Limpopo, Umbeluzi, Incomati and Maputo Rivers. Therefore, floods in Mozambique are due to both internal rainfall and water flows from neighbouring countries as a result of precipitation in the upstream countries, mostly linked with inefficient management of dams.

Although floods have negative impacts, they should not be looked only at that negative side. They are also part of an ecological regenerative cycle, by bringing nutrients to the soils, by incrementing agriculture productivity, by incrementing groundwater resources, by incrementing fish populations, among others. Thus major challenge, particularly to science and technology, is to minimise the negative effects of floods and maximise the benefits. Data on floods occurrence in the country are presented in Table 4.4.

Year	Description
2008	Zambezi, Buzi and Pungue rivers, 113,000 people affected; 20 deaths.
2001	Zambezi River, 115 deaths, 500,000 people affected.
2000	Limpopo, Maputo, Umbeluzi, Incomati, Buzi and Save Rivers; 640 deaths, 2,000,000 people affected; the worst in the last 150 years.
1999	Provinces of Sofala and Inhambane; highest precipitation levels in 37 years; 100 deaths and 300,000 people affected.
1997	Buzi, Pungue and Zambezi Rivers; 78 deaths and 300,000 people affected.
1996	All rivers in south; 200,000 people affected.
1985	9 rivers in the provinces of south; worst floods in 50 years after 4 years of droughts; 500,000 people affected.
1981	Limpopo River; 500,000 people affected.

Table 4.4: Occurrence of floods in Mozambique since 1980, from source [6]

Four classes of vulnerability to floods are considered:

- The risk of first level reaches 1.7 million of hectares in altitudes of less than 20 metres above sea level, and in a distance up to 10 km from the major hydrographical basins, representing about 6% of the national coverage. These areas can be inundated in years of medium to good rainfall;
- The risk of second level is defined for altitudes between 20 and 50 metres above the sea level, representing 2.7 million of hectares, meaning 9.6% of national firm land;
- The third level risk is defined for altitudes between 50 and 100 metres above sea level, with 10 km proximity to the main rivers, representing almost 4 million hectares (about 14% of the national coverage of firm land);
- The fourth level risk is less probable 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.

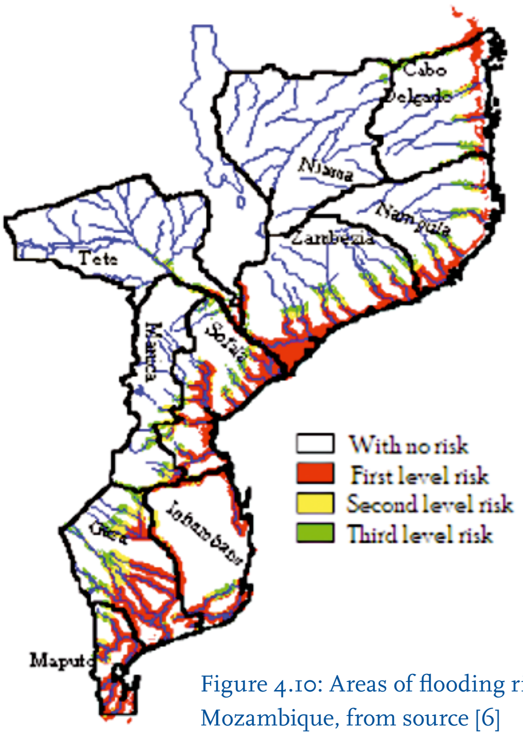


Figure 4.10: Areas of flooding risk in Mozambique, from source [6]

7. Vulnerability Analysis of the Water Sector

Water is a vital factor for the functioning of ecosystems, whether they are terrestrial systems, inland waters, coastal or marine systems, and consequently for guaranteeing biodiversity. In Mozambique, there are currently 34 conservation and protected areas, including transboundary conservation areas, covering more than 10% of the country's total area. The environmental requirements for water, in qualitative and quantitative terms, have not yet been determined and are an extremely important factor to be considered in any water resource management plan. Studies on the ecology and the state of conservation of the flora and forest resources indicate that most of the country's territory is covered by Miombo forest, with extensive areas of the Mopane forest in the Zambezi, Limpopo and Save valleys. It is precisely in these areas of savannah forest that most of the country's protected areas are located – the Gorongosa National Park, the Zinave National Park, the Banhine National Park, the Limpopo National Park, the Rovuma Reserve, the Maputo Elephant Reserve, the Marromeu Reserve and the Zambezi Wildlife Unit. Wetlands are also ecosystems of high conservation value. Their ecological functions are fundamental in the regulating of the water regime and in maintaining habitats, which are associated with high productivity and biodiversity. Since Mozambique is a coastal country, containing several major rivers that flow into the Indian Ocean, particular attention should be paid to these areas. In Mozambique the five ecosystems characteristic of wetlands are represented – the marine, estuarine, riverine, lake and palustrine systems. Quantitative and qualitative alterations in water resources could have serious environmental implications, the occurrence of which, however, has not yet properly studied in Mozambique.

Name	River	Nearest city	Type	Height (m)	Useful capacity (Mm^3)	Mean annual runoff (Mm^3)	Main objectives
Pequenos Libombos	Umbeluzi	Maputo	Earth	46	360	240	Urban supply, irrigation
Corumana	Sabie	Moamba	Earth	45	1,230	630	Irrigation, hidropower
Macarretane	Limpopo	Chokwe	Concrete	12	3.6	5,510	Irrigation
Massingir	Elefantes	Chokwe	Earth	48	2,260	1,800	Irrigation, hidropower
Mavuzi	Revue	Chimoio	Concrete	8	1.2	1,400	Hidropower
Chicamba	Revue	Chimoio	Concrete	75	1,820	680	Hidropower, urban supply
Chimoio	Mezingaze	Chimoio	Earth	15	0.3	-	Urban supply
Cahora Bassa	Zambezi	Tete	Concrete	171	39,200	80,000	Hidropower
Nampula	Monapo	Nampula	Concrete	17.5	4	2,350	Urban supply
Nacala	Muecula	Nacala	Earth	17	4.4	16	Urban supply
Chipembe	Montepuez	Montepuez	Earth	15.6	24	115	Irrigation
Locumue	Lucheringo	Lichinga	Earth	17.5	1.9	3	Urban supply

Table 4.5: Characteristics of Mozambique's large dams, from source [3]

The characteristics of the runoff regime of Mozambican rivers require the storage of water through dams so as to permit the intensive use of their water resources. The country is, however, poorly equipped in terms of essential infrastructures, with only a few large dams, and with a clear discrepancy when compared with the neighbouring countries – mainly South Africa and Zimbabwe. Table 4.5 shows the characteristics of Mozambique's large dams.

The total water storage capacity is currently about 56,000 Mm^3, with a useful capacity of 45,000 Mm^3, about 90% of it corresponding to the capacity of Cahora Bassa dam. The total useful storage capacity represents 21% of the mean annual flow of the country-s rivers. However, if Cahora Bassa is excluded, the remaining 5,800 Mm^3 of useful capacity represents only 5% of the mean annual runoff of the country-s rivers, excluding the Zambezi. A study dated at 1984 on some of the country's main rivers, showed that a storage capacity of 10-40% of the mean annual flow would be necessary, for a usage of 50% of the mean annual flow, with a reliability of 90%. New large dams are planned and are currently at various design stages. Among the most important ones are:

- Movene dam – for expanding irrigation in the Umbeluzi river;
- Moamba dam – for irrigation on the Middle and Lower Incomati and for Maputo water's supply;
- Chuali dam – for irrigation on the Lower Incomati;
- Mapai dam – for irrigation in the Limpopo basin;
- Bue Maria dam – for irrigation on the Lower Pungue and water supply for Beira city;
- Mphanda-Nkuwa dam – for hydropower production at the Zambezi river, downstream of Cahora Bassa;
- Alto Malema dam – for production of hydropower for Nampula and Nacala;
- Montepuez dam – for water supply for Montepuez, the marble industry and irrigation.

The fact that Mozambique's major rivers, with the exception of the Rovuma, rise in countries upstream from Mozambique makes the country very vulnerable in terms of availability of water, whether directly for human use or for the environmental needs of natural ecosystems, particularly estuarine areas. In fact, the increased construction of dams in upstream countries without assessing the environmental impact on ecosystems downstream has caused serious effects on estuarine ecosystems. Changes in the inundation regime that is characteristic of these ecosystems together with the reduced transport of sediments could have serious repercussions on their maintenance, affecting fish resources and many other species of fauna and flora.

The development of irrigation projects in arid zones in the south of the country, in areas formed by deposits of recent marine sediments, is a further intervention with environmental risks, namely increased salinity of the soil, with implications for the availability of water to supply the population. Deforestation and the removal of vegetation through slash and burn agriculture intensifies the erosive action of water, leading to the loss of soil through erosion. This also affects the quality of water because of the deposition of a larger amount of sediments.

Erosion is driven particularly by poor land use, both through poor agriculture practices and bad settlement policy, involving people building on areas with a high risk of erosion. This leads to frequent landslides, with damages for the population and for infrastructures.

One should also note the pollution generated in urban and industrial areas, both inside and outside the country, where sanitation infrastructures scarcely exist, particularly for the treatment of wastewater and for the controlled deposit of solid wastes.

Major vulnerability of the Mozambican population to both floods and droughts is linked to the weak national socio-economic infrastructure and extreme poverty[1] of the populations. In Mozambique, around 10 million people live in absolute poverty, according to PRPS. Figure 4.11 shows the relative absolute poverty distribution in different provinces of Mozambique.

At local level there are other factors contributing to aggravate the situation, like inappropriate agriculture practices, contributing to deforestation; inefficient or non-existence of better rivers management (lack of dams and reservoirs to control the water flows); poverty and inefficient disaster warning system. The use of river basins for household agriculture needs appropriate planning regarding the floods forecast. The lack enforcing measures to avoid people from building shelters along the

[1] People living in absolute poverty are defined as those living with less than US1.00 a day

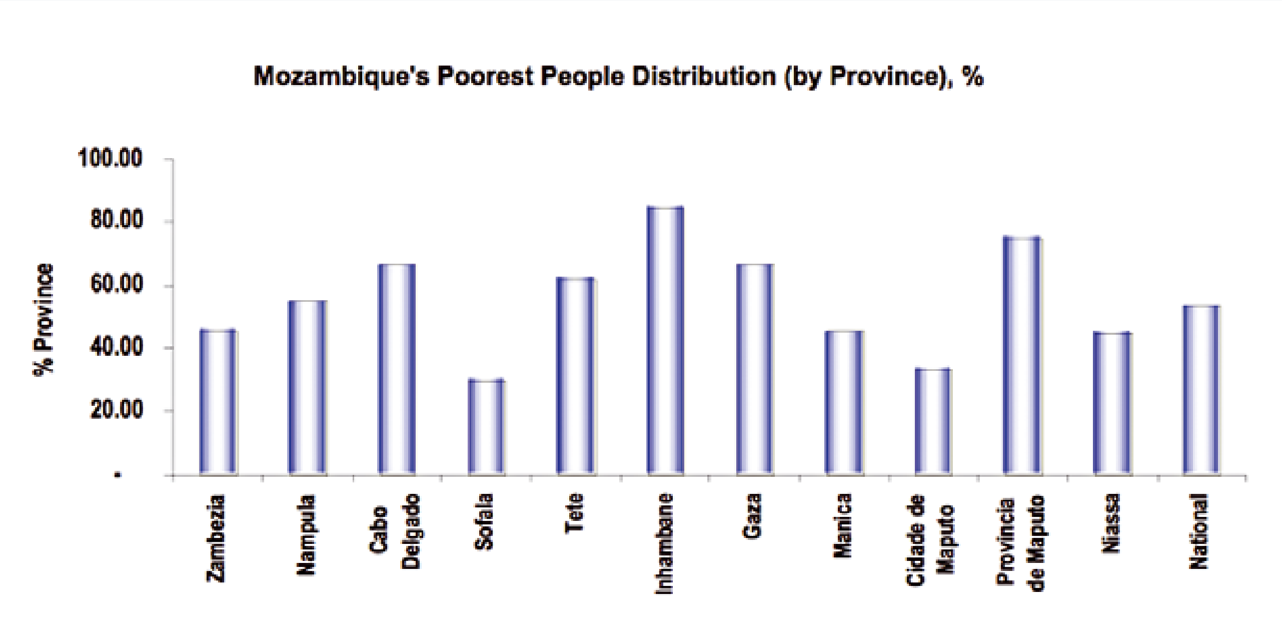


Figure 5.6: Absolute poverty distribution by Province in Mozambique, from source [6]

river basins contributes to enhance the vulnerability of people and their goods (including livestock) to floods. The drought response also depends on the capacity of the people to react in terms of food availability, water storage capacity, etc. Therefore, the poorer the victim, the stronger the vulnerability to any natural disaster will be. From this discussion, it becomes obvious that poverty and the level of vulnerability to natural disasters are interrelated.

8. National Response Capacity

In the last years there is a growing recognition of the need to adopt strategies to mitigate the impact of climate change and variability phenomena. This is reflected in the number of organisations involved, at both national and international levels. Here a summary of the major organisations involved is presented, with their mandates.

8.1 National institutions

8.1.1 Ministry for Coordination of Environmental Affairs (MICOA)

The major task of MICOA is the intersectorial coordination in view of a correct use of natural resources for the well-being of the society. MICOA has been undertaking mitigation actions to climate change and variability. MICOA defined the following measures for reduction of vulnerability, among others:

- Implementation of the strategy and action plan for biodiversity conservation, in the framework of the biodiversity convention;
- Implementation of the strategy and action plan for prevention of uncontrolled fires;
- Implementation of the strategy and action plan for prevention of soils erosion;
- Elaboration of the National Action Plan for Adaptation (NAPA) in the framework of the United Nations Framework Convention for Climate Change (UNFCCC);
- Implementation of the national capacity building plan for the clean development mechanism (CDM) in the framework of the Kyoto Protocol;

- Implementation of the project on self assessment of needs for national capacity building for global environment management;
- Implementation of the action plan for combating droughts and desertification in the framework of the United Nations Convention on Combating Droughts and Desertification.

8.1.2 National Institute for Disasters Management (INGC)
INGC is responsible for all issues related with mitigation of disasters in the country, with focus on natural disasters like cyclones, droughts, floods, and earth quakes, among others. Some of the INGC tasks in mitigating disasters are as follows:

- Dissemination of information on natural disasters situation;
- Organisation, coordination, analysis of meteorological information, its trends and impacts;
- Provision of assistance to communities; and
- Undertaking of pre disasters planning activities.

8.1.3 Technical Secretariat for Food Security and Nutrition (SETSAN)
SETSAN is a working group comprising professionals from various ministerial sectors, including non governmental organisations. The aim of the group is to work towards the establishment of food and nutritional security in the country. SETSAN activities have their focus on:

- Human capital development;
- Rehabilitation of key infrastructures; and
- Restoration of agriculture production.

8.1.4 Mozambican Red Cross (CVM)
CVM has been supporting a large part of vulnerable population in collaboration with governmental institutions, like the Ministry of Agriculture, the Ministry of Health, the National Institute for Disasters Management, among others.

8.2 International institutional support

International organisations have been supporting the activities of national agencies in the field of preventing natural disasters. The most important ones are presented in the next sections.

8.2.1 World Food Programme (WFP)
WFP works in collaboration with about 29 national and international institutions in Mozambique, particularly in the provinces more vulnerable to droughts and floods. WFP activities are oriented to food distribution in the areas mentioned. WFP activities are oriented to:

- Food distribution;
- Provision of supplementary food to children with less than 5 years of age;
- Food distribution in schools; and
- Implementation of emergency programmes, including issues related to HIV/AIDS.

8.2.2 United Nations Children's Fund (UNICEF)
UNICEF's activities in Mozambique have their focus in the field of health care for children and teenagers. Three strategies are used by UNICEF:

- Training provision to distrital and provincial directorates in matters related to planning, management and improvement of the health care services;
- Establishment of a structure which enables community participation in health assistance; and
- Dissemination of the appropriate approach about the necessary assistance to children and teenagers.

8.2.3 United Nations Development Programme (UNDP)
UNDP is involved mainly in the field of capacity building oriented to emergency situations associated to natural disasters. Some of UNDP activities are:

- Preparation of a national plan for disasters and establishment of a support network through NGOs and local governments, for strengthening of community initiatives for disasters prevention;
- Establishment of a fund for local and community support for mitigation of natural disasters;
- Improvement of geographic and demographic information in risk areas.

8.2.4 FEWS Net Mind
FEWS Net Mind activities are oriented to:

- Improvement of the early warning system;
- Support to contingency plans for response preparations to disasters;
- Improvement in use of information for disasters prevention.

9. Adaptation Strategies to Floods and Droughts

Extreme climate events, like floods and droughts, are very likely a result of greenhouse gas emissions at global level. This means that such phenomena should be viewed not just as local issues. The water sector can contribute to mitigate the greenhouse gas emissions by identifying and developing the hydroelectric potential available at different sites. Regarding adaptation measures to extreme climate events, they should be looked at international, regional, national and local levels.

9.1 At international level

Climate change is a global problem demanding global solutions. The solutions of climate change problems may be achieved of course by mitigation measures, which are taking part at global or international level. Nevertheless developing countries are already suffering from the impacts of climate change. Therefore there is a need to find ways to assist developing countries in building their adaptive capabilities. There are different initiatives supporting adaptation to climate change at global level like the recently created Adaptation Fund, the GEF initiative, the UNEO initiative, among others. Nevertheless additional measures, like the integration of climate change issues into development aid, should be considered.

9.2 At regional level

Both floods and droughts in Mozambique occur mainly in transboundary rivers basins. Important adaptation measures to be adopted are as follows:

- Strengthening of sharing of information among countries involved in river basins organisations;
- Strengthening of the river basins organisations;
- Strengthening the involvement of stakeholders in issues related to river basins organisations;
- Strengthening of hydro meteorological networks in river basins;
- Undertaking of common research programmes among countries sharing the same river basins, looking at different aspects of the basins;
- Undertaking of common training programmes on issues related to the management of river basins;
- Promotion of ecosystems approach in management of river basins.

9.3 At national level

According to IPCC 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 their occurrence, during and after the occurrence, as outlined in [7]. Major adaptation measures to be adopted can be summarised in short term, medium and long term, as outlined in the next sections:

9.3.1 Short Term

- Building of awareness of the relevance of climate change in development pathways, ensuring that climate change is recognised as relevant and urgent priority across sectors;
- Reinforcement of the early warning mechanisms;
- Reinforcement of institutions dealing with climate change adaptation and disasters management;
- Building of technological adaptation through construction of dams for water control and storage, use of groundwater resources, harvesting of rain waters, among others;

9.3.2 Medium Term

- Mainstreaming climate change into development, enabling that climate change issues are 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 disasters situation;
- Expansion of the hydro meteorological network and introduction of modern technologies for data collection, transmission and processing;
- Computerisation of hydrological databases and publication of the hydrological yearbooks, including systematic and regular exchange of information with neighbouring countries.

9.3.3 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 organisations to receive such information;

- Undertaking of comprehensive studies of water resources, both surface and ground, covering the different aspects, like physical, ecological, salt intrusion issues, among others.
- Promotion of use of water desalination technologies for both sea waters and waters from boreholes, which in many cases have high content of salt in arid and semi arid areas.

9.4 At local level

For local communities climate change is a day-to-day reality. A study undertaken in communities in Mozambique [8] reveals that the local communities have observed significant changes in their climates. Their feeling is that rainwater is getting scarcer and unpredictable. On the other hand when there are floods their intensities are very strong. Thus survival is getting more difficult than some years ago.

The communities have to adapt to this change of the weather patterns. At this level, adaptation is more based on share of knowledge and experience, as the life of the communities is more based on natural resources. Adaptation measures at local level can be summarised as described in the next sections.

9.4.1 Short and Medium Term

- Settlement of populations in appropriate places, taking into account both floods and droughts;
- Reinforcement of the early warning mechanisms;
- Dissemination of techniques for harvesting rain water;
- Promotion of plantation of fast maturing crops and crops resistant to droughts;
- Promotion of plantation of native fruit trees, due to their capacity to adapt to different water stresses.

9.4.2 Long Term (Community Based Adaptation)

- Promotion of sharing of knowledge and experience among communities inside and outside the country, whereby researchers act as facilitators using new ways of communicating findings, like use of VIDEO, Mass Media, direct interaction with communities, etc.

10. Conclusions

Compared with other parts of the world, Mozambique has a shortage of water. Indeed in Mozambique per capita water availability is below the African average. According to IPCC the region will be affected by decreasing water availability due to the impacts of climate change. This will lead to droughts as major trend, but also floods will occur and with greater intensities. Both droughts and floods will affect particularly the transboundary rivers basins because of inefficient water management schemes in the region. Water scarcity in Mozambique will lead to saline water intrusion in both surface and ground water, among other impacts. Adaptation to these phenomena will require undertaking of appropriate measures at international, regional, national and local levels. At international level support is necessary for developing countries to cope with the challenges of adaptation to the changing climate. The country is located downstream of the major transboundary rivers basins, and it is in the areas of such basins that both floods and droughts occur with higher intensities. Both calamities are driven by natural phenomena of availability or no availability of rain and also by inefficient management of dams. Therefore regional collaboration among countries sharing the same river basins is essential. At national and local levels the mainstreaming of climate change into development and the building of resilience are very important issues. The development of vulnerability and disaster management strategies should be an important goal to achieve.

References

[1] IPCC Fourth Assessment Report, 2007;
[2] Saleemul Huq "Comment and Analysis: Prepare for the Worst", www.newscientist.com, 29 March 2008;
[3] National Directorate of Water "Water Resources of Mozambique", Maputo, 1999;
[4] "SAHIMS ATLAS Limpopo Basin Project", http://www.sahims.net/gis/Gis%20Input/moz_map_index_limpopo.asp;
[5]"The Joint Pungwe Project", http://pungweriver.net;
[6] Ministry for Coordination of Environmental Affairs "Measures for Adaptation to Climate Change", Maputo, December 2005;
[7] European Parliament "Financing climate change policies in developing countries", 2008;
[8] UEM and UNN "Climate change studies in Mozambique", 2006.

Chapter 5

The Ecosystem Approach to Climate Change Adaptation in Africa River Basins

By Hillary M Masundire. Chair, IUCN Commission on Ecosystem Management. Department of Biological Sciences. University of Botswana. Gaborone, Botswana

Contents

1. Introduction

Simulations made by the Intergovernmental Panel on Climate Change, (IPCC) estimate reductions in precipitations in southern Africa in the next 100 years, increases in East Africa and uncertainty in the Sahel (IPCC, 2001). The Nile River Basin simulations indicated a potential increase in precipitation of about 10% with no change anticipated in runoff. The Zambezi and Limpopo River Basins are anticipated to experience reduction in precipitation of 5 to 20% with a decline in runoff of 25 to 40%.

This will certainly have a significant impact on availability, access to and management of water resources; especially in southern Africa where critical water shortages in both industry and domestic sectors are observed during what used to be "normal" drought episodes (Magadza, 1996, 2000).

More than 60% of Africa forms part of catchments for shared river basins – transboundary river basins. Rivers such as the Nile, Senegal, Niger, Volta, Congo and Zambezi have their drainage basins (catchments) extending into several countries. In southern Africa, 11 countries share 7 river basins – Zambezi (8 states), Limpopo (4 states), Orange/Senqu (4 states), Okavango (3 states), Ruvuma (3 states), Cunene (2 states) and Komati (3 states). Some of the countries are components of several of these transboudary river basins – Angola (4), Botswana (4), Mozambique (4), South Africa (4) and Zimbabwe (2). According to the Southern African Development Community (SADC) Water Policy (2005), the region has 15 major river basins which are transboundary or watercourses shared by two or more countries.

The Southern African Development Community (SADC) has been trying to effectively manage shared water resources and has met with the following challenges:

- Weak legal and regulatory framework.
- Inadequate institutional capacities of national water authorities, and regional or river basin organizations.
- Weak policy framework for sustainable development of national water resources.
- Poor information acquisition, management and dissemination systems.
- Low levels of awareness, education and training with respect to economic, social, environmental and political issues related to water resources development and management.
- Lack of effective public participation by all stakeholders particularly women and the poor.
- Infrastructure is inadequate and unable to meet the growing demands for service. (SADC Water Policy: www.sadc.int).

Management of water resources of transboundary river basins necessarily requires the cooperative participation of the countries that share the basin. This necessity is felt mostly by downstream states and less so by upstream states. The same state may be upstream with respect to one basin while it is downstream with respect to another. For example, Botswana is downstream of the Okavango River basin and therefore feels the need of such cooperation on the management water resources of this basin. However, because Botswana is upstream in the Limpopo River basin, it may not feel so compelled to cooperate with downstream states in regard to the water resources of this basin. Glieck (1993) estimated that 94% of surface water in Botswana originates from outside its borders. Mozambique, being coastal, is at the downstream of the Zambezi, Limpopo and Komati River basins.

This paper proposes that effective management of water resources of transboundary river basins should be based on applying the ecosystem approach (www.cbd.int). The paper begins by explaining what the ecosystem approach is and suggests how the approach may be used in the management of transboundary river basins to mainstream adaptation strategies for climate change.

2. What is the Ecosystem Approach?

The ecosystem approach is a strategy for the integrated management of land, water and living resources (ecosystems) that promotes conservation and sustainable use in an equitable way. Thus, the application of the ecosystem approach will help to reach a balance of the three objectives of the Convention on Biological Diversity: conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. (www.cbd.int).

The approach is guided by a set of 12 principles.

1: The objectives of management of land, water and living resources are a matter of societal choice.

2: Management should be decentralized to the lowest appropriate level.

3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

4: Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should: (a) Reduce those market distortions that adversely affect biological diversity; (b) Align incentives to promote biodiversity conservation and sustainable use; (c) Internalize costs and benefits in the given ecosystem to the extent feasible.

5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

6: Ecosystems must be managed within the limits of their functioning.

7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

8: Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

9: Management must recognize that change is inevitable.

10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

In applying the ecosystem approach to river basin management, one is urged to

- Focus on the functional relationships and processes within ecosystems
- Enhance benefit-sharing
- Use adaptive management practices
- Carry out management actions at the scale appropriate for the issue being addressed, with decentralization to lowest level, as appropriate
- Ensure inter-sectoral cooperation.

3. Conceptual Framework: Ecosystem Services

The Ecosystem Approach aims to achieve sustainable use of ecosystem services in order to sustain human livelihoods and human well-being. Ecosystem services are defined as

- "the benefits of nature to households, communities, and economies",
- the fundamental life-support services provided by natural ecosystems, without which human civilization would cease to thrive,
- the conditions and processes through which natural ecosystems, and the species that compose them up, sustain and fulfil human life or
- the benefits people obtain from ecosystems. (Millennium Ecosystem Assessment www.maweb.org).

The Millennium Ecosystem Assessment identified four categories of ecosystem services.

3.1 Provisioning services

Most humans readily understand provisioning services – also called goods. These are usually tangible products from ecosystems that are usually extracted for human use and, hence, benefit. Broadly defined these include

- Biotic materials: food, fibre, biochemicals, timber, grass etc – domestically produced or harvested from the wild.
- Non-biotic materials – water, sand, gravel, minerals, air (gases)

Examples include mineral resources, water, timber, sand, food (fish, game meat, crops, and wild edible plant products), medicinal plants, natural oils etc. The other three categories of ecosystem services are less understood.

3.2 Regulating services

The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases. Included in this category are such services as flood mitigation, water purification and natural detoxification. Many people only realise and appreciate the benefits of this type of ecosystem service when the service is "lost" or is no longer available. The protective value of relatively undisturbed mangrove forests and corals were only realized by the majority of people after the Indian Ocean tsunami of 2004 (Sudmeier-Rieux et al, 2006). Wetlands greatly improve the quality of water flowing into them so making the purification of such water to make it potable much easier than it would otherwise be (Emerton, 1997). The water in the Okavango River has high turbidity before passing into the Okavango Delta and leaves the delta as very clean, clear water. Flash floods are increasingly being observed in areas where catchments have experienced extensive deforestation. Much of the current debate on paying for ecosystem services is mostly in regard to regulating services where nature provides a service for which humans would have had to pay, often large amounts of money, to enjoy.

3.3 Cultural services

The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values. Nature- and eco-based tourism is the more easily recognizable of this group of services. Most humans do not realise the value of some of these services until they been lost – much the same as in regulating services.

3.4 Supporting services

These are the services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat. One may look at this suite of services as the "existence value" of an ecosystem. It is because a wetland exists that it is possible for us to obtain the services provided by the wetland. If there are no forests, then we cannot get forest ecosystem services. In addition to mere existence, these various ecosystems perform functions such as nutrient cycling, nutrient enrichment, primary production etc – which form the basis of the other three groups of services.

4. Models of Sustainability

Current debates on sustainable development are driven by the following model

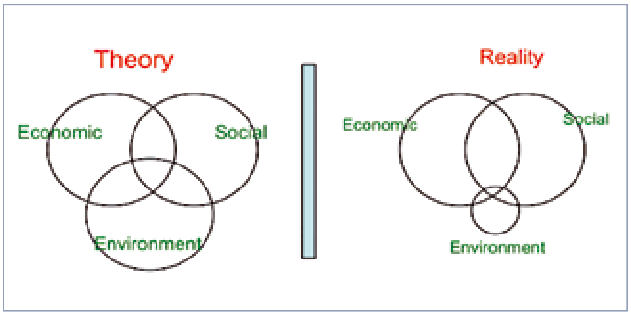


Figure 5.1: Model of Sustainability (left) and Unsustainability (right).

In order to attain sustainability, it is suggested the attention given to the environment be increased to equal the attention given to the social and economic sectors.

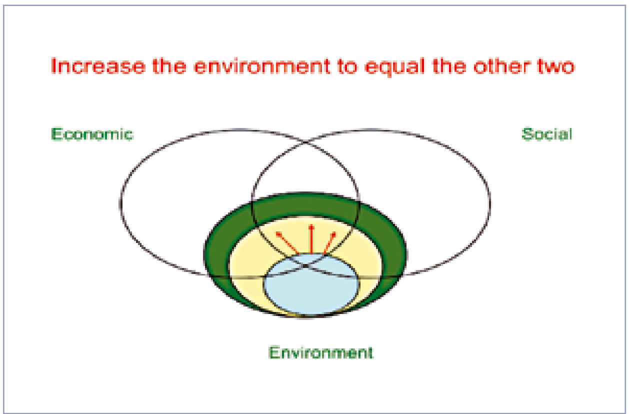


Figure 5.2: Towards Sustainability?

I argue that this model does not lead to sustainability at all. Since the social and economic sectors are supported by, and are therefore dependent on the ability of ecosystems (the so-called environment sector) to provide ecosystem services, then sustainability should be viewed as below.

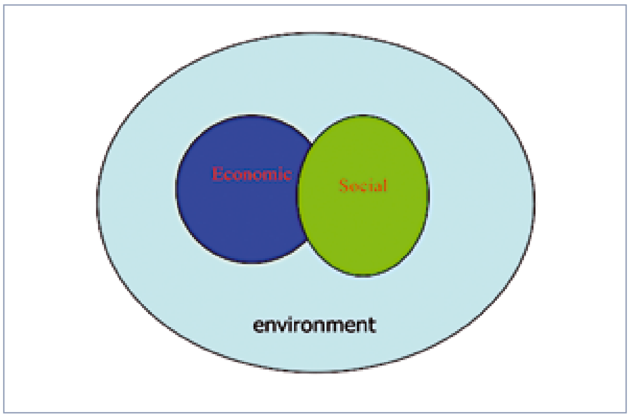


Figure 5.3: "Correct" Model of Sustainability.

What we see depicted as unsustainability (Fig. 5.4) should be viewed as below.

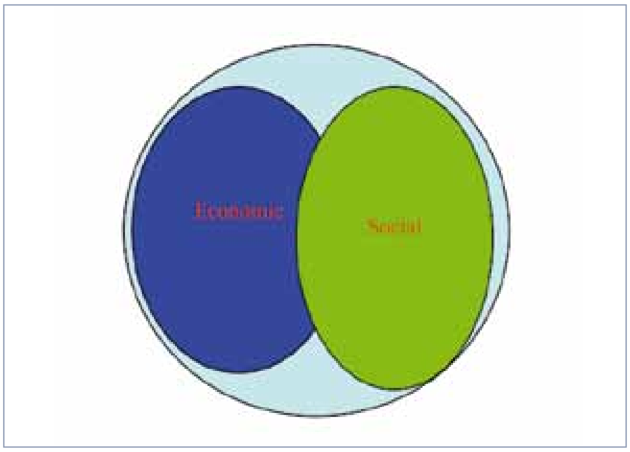


Figure 5.4: Model of Unsustainability.

5. The Millennium Assessment Conceptual Framework

The ecosystem approach relates very well with the conceptual framework developed through the Millennium Ecosystem Assessment project (MA, 2005). This highlighted the critical importance of ecosystem services in sustaining human livelihoods. The conceptual framework developed by the MA is presented in Figure 5.5.

The conceptual framework of the MA not only highlights the linkage between ecosystem services and human well-being, but also identifies points on human interventions that would lead to realization of the model of sustainability proposed above. The Ecosystem Approach provides the framework for the human interventions.

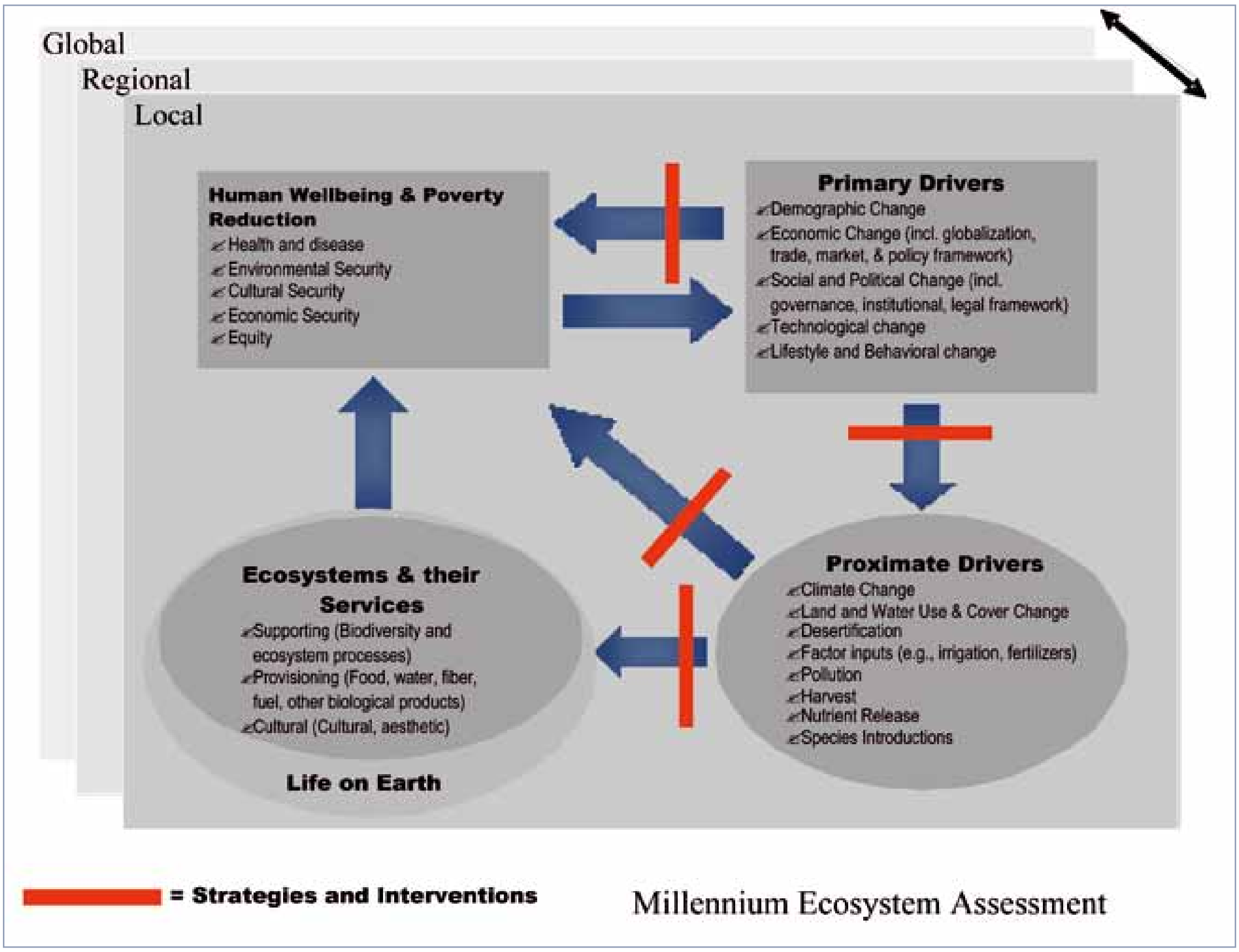


Figure 5.5: The Millennium Ecosystem Assessment Conceptual Framework (MA, 2005).

6. Climate Change as a Driver in Transboundary River Basin Ecosystems

Climate change has been identified as one of he key drivers to both ecosystem structure and function (MA, 2005). Thus climate change will affect the ability of ecosystems to provide necessary services. These effects will be expressed through alterations to hydrological cycle – the balance between temperature and rainfall. For example, the anticipated reduction in precipitation and run-off in southern African river basins will affect

- The very existence of rivers and
- All the other ecosystem services associated with these river basins including
  - Water supply
  - Hydropower generation
  - Agricultural production and provision of food
  - Timber and non-timber forest products
  - Wildlife and livestock grazing
  - Special habitats for some species – especially those that may be endangered.

Human interventions with respect to climate change are generally responses to human-induced causes of climate change. The main human-induced contributions to the greenhouse effect are the burning of Fossil Fuels and forest fires. Zhang et al, (2007), claimed that humans have „contributed significantly to observed increases in precipitation in the Northern Hemisphere mid-latitudes, drying in the Northern Hemisphere subtropics and tropics, and moistening in the Southern Hemisphere subtropics and deep tropics" and that the observed changes are larger than those projected from model simulations and „may have already had significant effects on ecosystems, agriculture and human health in regions that are sensitive to changes in precipitation, such as the Sahel" of Africa. Pitman et al (2004) also demonstrated that large-scale land cover changes may have caused significant changes to the climate in western Australia and that these climate impacts can be reversed through equally large-scale reforestation.

Acting on human-induced causes of climate change within transboundary river basins definitely calls for the application of the ecosystem approach. This is so because uncoordinated policies and/or actions in countries sharing the same basin can exacerbate the negative impacts of human-induced climate change. If the ecosystem approach is used at a river basin level as proposed below, effective responses to climate change and its impacts are likely to be achieved.

7. How to Apply the Ecosystem Approach to River Basin Management

A starting point in applying the ecosystem approach proposed by the Convention on Biological Diversity (CBD) is to turn each of the 12 principles into a question (www.cbd.int):

1. How do you involve all members of society in decisions associated with the management of land, water and living resources?
2. How do you ensure management is decentralised to the lowest appropriate level?
3. How do you ensure the effects of management actions (potential or actual) on adjacent and other ecosystems are taken into account?
4. How can the economic context be understood so that market distortions that affect biological diversity are reduced, incentives are developed to promote biodiversity and sustainable use and ecosystem costs and benefits are externalised?
5. What measures could be used to conserve ecosystem structure and functioning so as to maintain ecosystem services?
6. What measures can be taken to ensure ecosystems are managed within the limits of their functioning?
7. What actions can been taken so that the problem(s) is (are) addressed at the appropriate temporal and spatial scales?

8. How can varying temporal scales and lag-effects be taken into account when considering the sustainable use of ecosystems?
9. How can adaptive management be used to address the problem(s) identified?
10. How can an appropriate balance be sought between, and integration of, conservation and use of biological diversity?
11. How do you ensure all forms of relevant knowledge including, scientific, indigenous and local knowledge, innovations and practices are included?
12. What measures can be taken to facilitate the involvement of all stakeholders including all sectors of society and scientific disciplines?

In order to apply the ecosystem approach in climate change adaptation in river basins, the following guidelines are proposed. These guidelines should be used in accordance with relevant legislation such national and/or regional Environmental Impact Assessment (EIA) legislation. River Basin Organization (RBOs) or River Basin Authorities (RBAs) would be the most appropriate institutions where they exist. In southern Africa, the SADC Treaty and its Revised Protocol on Shared Watercourse Systems (www.sadc.int) has provided an enabling environment for the development and establishment of institutions such the OKACOM (Okavango River Basin), ZAMCOM (Zambezi River Basin), KOBWA (Komati River Basin), LIMCOM (Limpopo River Basin) and ORASECOM (Orange-Senqu river Basin). These institutions should play a leadership role in applying the ecosystem approach to mainstreaming adaptation strategies in climate change in these transboundary river basins. There is also need to work across basins as some of the causes and effects of climate change transcend basin boundaries.

Applying the ecosystem approach will translate various policy pronouncements by the SADC into real action on the ground. Some of these pronouncements include

The Southern African Vision for Water, Life and Environment adopted in March 2000, aimed at "equitable and sustainable utilisation of water for social and environmental justice, regional integration and economic benefit for present and future generations".

The Revised SADC Protocol on Shared Watercourses, which entered into force in September 2003, whose objective is "to foster closer cooperation for judicious, sustainable and coordinated management, protection and utilisation of shared watercourses and advance the SADC agenda of regional integration and poverty reduction".

Figure 5.6: Southern African river basins.

7.1 Planning Issues/Objectives (Principles – 1, 2, 11, & 12)

The starting point for applying the ecosystem approach in dealing with strategies for adapting to climate change in transboundary river basins must be the identification of a required or desired action and/or policy. This could be a single issue or a set of issues. This can be referred to as "problem identification" leading to objective setting. These could include

- water resources development
- hydropower generation
- waste disposal and pollution control
- mining
- road construction
- infrastructure development
- irrigation
- grazing land
- decommissioning of infrastructure
- land use change
- land cover change
- reforestation programme

Any or several of these could emanate from one or more the basin states.

7.2 Strategic impact assessment (Principles – 3, 4, 5, 6, 7, 8, 9, 10, 12)

In order to define the boundaries of planned activity, the potential impact of the planned activity in both space and time needs to be identified. This calls for a Strategic Environmental Assessment (SEA) that considers the potential ecological, social and economic impact of planned activity. Such analysis must consider both positive and negative impacts arising

- directly and indirectly from the planned activity
- from the combined effect of the planned activity and other activities already going on in both the plan and adjacent areas
- from the combined effect of the planned activity and other planned activities in the same plan and adjacent areas.

The possible impacts of planned activities should be looked at in terms of space – area of impact and time – duration of such impacts (Principles 3, 7 & 8).

For example, the construction of dam on a tributary of a transboundary river will have an effect on the hydrology of the main river. Countries sharing the same river basin must consider actions on tributaries together with those on the main river itself. This may be seen as posing a challenge to the "sovereignty" of states. A minister responsible for water development in one SADC country was quoted as saying "we must not let any drop of rain that fall on our land flow outwards".

In considering climate change impacts, we need to take into account the cumulative effects of all activities within a basin and not just for individual projects. Applying the ecosystem approach should enable planners to bring all the relevant stakeholders together to deal with such issues.

7.3 Scale: Space and time (Principles – 3, 7, 8, 11 & 12)

Planners should consider the spatial extent of the proposed planned project. This can be called the project impact area. For examples it has been demonstrated that some emissions from southern Africa, are picked up as far north as Mount Kenya (Kenya) (Henne et al, 2006). Thus in regard to climate change causes and impacts, one may need to go beyond a given river basin.

It should be determined whether the proposed development/project/policy is

- Intra-basin – all aspects (inputs, outputs & effects) of the planned activity/policy are within the one basin. This may be within a sub-basin (tributary basin) or several sub-basins.
- Inter-basin – are those aspects (inputs & outputs) of the project outside the one basin
- International /intercontinental – are some aspects (inputs & outputs) of the planned activity/policy likely to be perceived outside the basin even beyond the continent e.g. habitats for transcontinental migratory species such as birds.

Planners should also consider the temporal scale with regard to the effects of projects. Effects may be positive or negative. These effects can be classified as

- short-term:– effects will be felt/observed within 0–5 years of a projects initiation
- medium-term:- effects will be felt/observed within 10 years of a projects initiation
- long-term:- effects will be felt/observed beyond 10 years of a projects initiation.

Planners should consider the temporal cumulative and synergistic effects of a planned activity in relation to other on-going or planned activities in the plan area and, where appropriate, adjacent planning areas.

7.4 Stakeholders analysis (Principles 1, 2, 12)

The objectives of ecosystem management are a matter of societal choice. Who is society? Planners should identify all the stakeholders likely to be affected – positively and/or negatively.

These should be ranked in terms of

- **Primary:** those directly affected by the proposed activity/policy and who cannot avoid the negative impacts of the proposed activity; for example, if a planned activity will lead to displacement of people or if a planned activity will cause an increase in prevalence of a particular disease. Primary stakeholders usually cannot avoid impacts from the planned activity. This should also include the "environment" – the biophysical environment that will directly impacted by the planned activity. These may include those outside the district in which plan is to be implemented.
- **Secondary:** those who will benefit from the proposed activity but will not directly feel the negative consequences. These may include those outside the district in which the plan is to be implemented.
- **Tertiary**: those that will benefit from the planned activity but can get similar benefits from elsewhere and will not be directly negatively impacted by the planned activity. These may include those outside the district in which a plan is to be implemented.
- **Unrepresented:** these stakeholders who cannot represent themselves e.g. nature, the young and unborn children.

For example: Diverting water from the Okavango River upstream of the Okavango Delta may affect the following:

- Local inhabitants in villages such as Seronga, Gumare, Etsha
- Tour operators at camps in the delta area
  International tour companies with subsidiaries operating in the delta
- Travel agencies that arrange packages for tourist into the delta
- Employment in the service industry in Maun supporting tour activities in the delta.

In this example,

- The inhabitants of the villages do not have much, if any, options. They are directly dependent of the resources of the delta such that the proposed activity (diversion of water from the Okavango River) will direct impact on their livelihoods and survival options. These are the **Primary stakeholders** in this example.
- Tours operators at camps in the delta are also directly dependent on the river and its hydrodynamics. Thus the planned activity in the example will directly impact on their operations. They are therefore also **Primary stakeholders.**
- International tour companies with subsidiaries operating in the delta will be affected. However, because they have other operations elsewhere, if operations in the Okavango Delta become less viable, they can close and expand or concentrate on their operations elsewhere. They are therefore **Secondary stakeholders**.
- Travel agencies – these will shift their attention to selling more viable destinations and may not really feel much of an impact. They are **Tertiary stakeholders**.
- Service industry in Maun – here they will a mixture of some **primary** – those solely servicing the delta-based tourist activities and some **secondary**- those, e.g. fuel suppliers who will still remain viable because of the wider customer base.

In this example concerns for nature – the vegetation, water and aquatic life forms, terrestrial animals that will be affected by the planned activity also need to be represented in the stakeholder analyses. There is also need to consider to the needs of future generations in setting up development objectives.

7.5 Institutional analysis (Principles 1, 2, 11, 12)

In 1 – 4 above, the relevant institutions should be identified. These should be identified at all levels from local resource users, through to national institutions, regional or trans-boundary institutions and to global institutions. Relevant private sector and civil society institutions should also be identified and engaged. The hierarchical and functional relationships of these institutions must be established and utilized to the maximum possible benefit – this means lateral and vertical linkages.

7.6 Ecosystem structure and function (Principles 2, 3, 4, 5, 6, 11 and 12)

It is critically important to identify

- key ecosystem structures
- key ecosystem functions and
- key ecosystem services in the plan area.

Ideally, all relevant stakeholders should be involved in this exercise. The outcome of this analysis will include an inventory of ecosystem services in the plan area as well as the likely impacts of planned activities on the structure and function of the ecosystem and on the ecosystem services derived from the plan area. Inventory of ecosystem services may also be called "Resource Inventories". These ecosystem services should ideally be mapped over the plan area. This involves working across national boundaries and, in some cases, across continents.

Caution: It is unlikely that all the relevant ecological information on ecosystems will even be known at any one time. Planners must therefore use the "Precautionary Principle" and the "best available science" to inform their decisions.

7.7 Economic issues (Principles – 3, 4, 6, 8, 10, 11 and 12)

Ecosystem services should, to the greatest extent possible, be valued. Valuation should include, but not be limited to, economic or monetary valuation. Models and methods of total economic evaluation should be used to achieve this. Valuation of ecosystem services is a very important decision making tool in development planning and implementation. Considering the four types of ecosystem services described above, some of the less understood services may be the most important in some situations.

Planners must consider all forms of economic utilization of the ecosystem service in the plan area with a view to reducing or removing any perverse economic incentives. For example, if industry is not made accept responsiblity for their specific impacts on the environment, they will not operate in an "environmentally responsible" manner. Planners need to apply concepts such as "the polluter-pays principle" in order to internalize negative impacts arising from domestic and industrial operations.

In such a context, perverse economic incentives can be considered the passing of the cost of environmental damage caused by one or some individual on to us all. For example, only car owners pay vehicle licenses for use of the roads – which is proper. In contrast, in Botswana the state funds, through public taxes, a "Livestock Control Patrol" system responsible for driving stray cattle and donkeys away from roads to avoid car accidents: Making the general public pay for clearing livestock owned by individuals from public roads can be viewed as perverse. This is because it passes the cost of caring for livestock to the general public while economic benefits accrue to the livestock owner. Perhaps the approach ought to be that all livestock roaming along public roads is impounded and the owners would redeem it upon payment of a fine, then the livestock owners would take more responsibility on their animals.

This also calls for a careful analysis of the possible consequences of some of the investment promotion incentives that may, in the medium- and long-term turn out to be perverse. Fast tracking developments that require detailed EIA according the EIA Act of 2005 is an example. Planners should guard against short-term economic (financial) gains that may have long-term negative ecological and social consequences (Principle 8).

7.8 Adaptive management in space and in time (Principles – 3, 4, 7, 8, 9 and 12)

Change is inevitable (Principle 9). This may be due to natural causes or may be human-induced. Planners should be adaptable, especially in regard to implementing plans given that unforeseen changes may occur. For example the sudden discovery of a valuable mineral resource and the need to exploit it will lead to changes, some of them drastic, to existing plans. Changes may also occur from "outside". For example, a drop or increase in demand for or value of a particular ecosystem service may lead to changes in existing plans. There ought, therefore, to be mechanisms in place to allow for rapid responses where necessary and appropriate. Adaptive management leads to feedback steps that allow one to review any of the steps describe above.

8. Capacity Issues

In order to effectively and rapidly mainstream the Ecosystem Approach into climate change adaptation strategies in transboundary river basins, there is urgent need to build and/or enhance knowledge and understanding of the concept of the ecosystem approach and how to apply it. Capacity issues should be approached in three aspects: (1) awareness raising, (2) capacity building and (3) capacity enhancement.

8.1 Awareness raising

All sectors of the society need to be made aware of the concept of the Ecosystem Approach and how, when, where and why it should be applied. Awareness raising campaigns should be devised to meet the needs of specific target audiences. Top government, civil and business leaders need messages and approaches that are different from what villagers, the youth, members of parliament, councillors and others need. Awareness-raising can be viewed as "marketing" the Ecosystem Approach. This task requires collaboration between experts on the Ecosystem approach and media or communication experts who design and package awareness campaigns. The transboundary river basin organizations (RBOs) and authorities (RBAs) need to take a lead in this.

8.2 Capacity building

Those involved in river basin usage and management at all levels need more focused capacity building. This requires both formal and informal training on the concepts of the Ecosystem Approach and the guidelines to apply it given above. This can be achieved with "tailor-made" in-service courses for practitioners whose activities have a bearing on land use. The Ecosystem Approach should be included into formal education curricula from pre-school to tertiary institutions, as appropriate.

8.3 Capacity enhancement

Those practitioners involved in capacity building will need their capacity to be enhanced through further needs-specific training. There is a need therefore for trainers and/or training institutions to be available to provide both capacity building and capacity enhancement.

9. Concluding Remarks

It is my view that the ecosystem approach offers opportunities and potential for holistic responses and adaptation to climate change. While governments are structures in sectors, the ecosystem approach advocates for inter-sectoral cooperation, collaboration, joint planning and joint implementation of development planning. The challenge is to make the approach understandable and appealing to those who need – all development practitioners. The other challenge is integrating the working of public and private institutions and sectors that do not currently work together. For example, sectors such as mining, agriculture, transport, military and health that are not considered "environmental" often have tremendous impact on ecosystems. Some of these impacts will definitely be exacerbated by climate change.

This paper aimed to demystify the ecosystem approach by proposing an easy-to-follow step by step guide to implementing the approach. Face to face dialogue is needed through in-service training: workshops and other publicity approaches in order to mainstream the approach. In Decision IX/7 the parties to the CBD at the 9th Conference of Parties reiterated their commitment to implementing the ecosystem approach but many parties called for assistance in regard to capacity building.

References

Xuebin Zhang, Francis W. Zwiers, Gabriele C. Hegerl, F. Hugo Lambert, Nathan P. Gillett, Susan Solomon, Peter A. Stott & Toru Nozawa (2007). Detection of human influence on twentieth-century precipitation trends. Nature advance online publication 23 July 2007 | doi:10.1038/nature06025

Pitman, A. J., G. T. Narisma, R. A. Pielke Sr., and N. J. Holbrook (2004). Impact of land cover change on the climate of southwest Western Australia, J. Geophys. Res., 109, D18109.

S. Henne (1), J. Klausen (1), J.M. Kariuki (2), B. Buchmann (1) (2006). Long range air pollution transport towards Eastern Africa as observed from Mt.Kenya GAW station.

Magadza, C.H.D., 2000. Climate change impacts and human settlements in Africa: prospects for adaptation. Environmental Monitoring, 61, 193-205.

IPCC (2001). Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability. IPCC Third Assessment Report „Climate Change 2001" and the Synthesis Report.

Gleick, P.H. (ed.) (1993). Water in Crisis: A Guide to the World's Fresh Water Resources. Oxford University Press, New York.

Sudmeier-Rieux, K; H. Masundire, A Rizvi and S Rietbergen (2006). Ecosystems, Livelihoods and Disasters: an integrated approach to disaster management. IUCN. Ecosystem Management Series 4. 57pp.

Websites: www.cbd.int / www.maweb.org / www.sadc.int

Chapter 6

Infrastructure Management in a Changing Environment: Strategies and Actions to Adapt the Management of Reservoirs

Experiences of the Komati Basin Water Authority

By Enoch M. Dlamani. Manager, Komati Basin Water Authority. Melalane, South Africa/Swaziland

Contents

1. Abstract

This paper discusses strategies and actions to adapt the management of reservoirs in a climate change environment. The paper presents a case of the management of reservoirs in the Komati River Basin, a transboundary river basin shared by the southern African States of the Republic of Mozambique, South Africa and the Kingdom of Swaziland. In particular the paper focuses on the dams managed by the Komati River Basin Authority, a bi-national company established by the Kingdom of Swaziland and the Republic of South Africa to implement Phase 1 of the Komati River Basin Development Project, comprised of the Maguga Dam in Swaziland and the Driekoppies Dam in South Africa.

The report discusses climate in the Komati River Basin that is dominated by dramatic inter-annual changes in rainfall, characterised by prolonged severe droughts that are often broken by spells of high rainfall. This variability of rainfall affects the agricultural industry that is dominant in the basin, has particularly detrimental effects on the poor rural communities and hinders the sustainable management of environmental resources. Major droughts in the Komati River Basin include 1926–1933, 1981–1984, 1991–1996, and 2001–2004. Some of the worst floods in the Komati River Basin include the 1984 Cyclone Domoina floods and the 2000 floods that decimated Mozambique. These climatic events linked to the El Nino effect have a decadal variability with a cyclic variation between 18 and 20 years. These climate variations have affected water resources management in the Komati River Basin. As a result, several dams have been constructed in the Komati River Basin to stabilize water supplies.

The management of dams in the Komati is also affected by the climatic variations. This paper discusses some of the challenges posed by climatic variation in the management of reservoirs and details some of the strategies and actions used to adapt reservoir management to climate change. The strategies and actions for adapting the management of reservoirs for climate change in the Komati River Basin include a re-evaluation of legal, technical and economic procedures for managing water resources in light of climate change. For reservoirs this involves a re-examination of engineering design criteria, operating rules, contingency and emergency preparedness plans, and water allocation policies. Water demand management and institutional adaptation have become the primary components for increasing system flexibility and resilience to meet the uncertainties of climate change. There is a shift from the traditional supply-sided water management approach of relying on the construction of large infrastructure to a demand management approach. Thispaper discusses how these strategies and actions are applied to adapt the management of reservoirs to climate change in the Komati River Basin. Finally, some conclusions and recommendations on strategies and actions that could be applied elsewhere to adapt the management of reservoirs to climate are offered.

Key words: Climate change, reservoirs, Komati Basin, real-time, operating rules

2. Introduction

Global warming due to anthropogenically-induced high atmospheric concentrations of greenhouse gases is widely understood in the scientific community to be causing the to global climate change. According the Intergovernmental Panel on Climate Change (IPCC), the climate change phenomenon could lead, inter alia, to, increases in the probability of extreme warm days, drier southern and the northern latitudes, and wetter tropics, increases in climate variability and the frequency of severe weather events; loss of wetlands, water quality degradation, and decreases in soil moisture content (IPCC, 2001).

The IPCC predicts that, generally, the warmer climate is likely to be accompanied by an increase in global precipitation of up to 4% for every degree Celsius warming of the planet. However, the effect will vary geographically with some places getting wetter and others drier. In Africa, precipitation will increase in the wet tropics and decrease by more than 10% in the drier subtropics, which include large tracts of southern Africa, where annual runoff is projected to decline by up to 25% by 1050. While it is acknowledged that there are many uncertainties inherent in the assessment of the impacts of climate change, especially on extreme events such as floods and droughts, logical inferences indicate that they are likely to be more severe, more frequent and cover larger spatial extents than before (Rouault et al., 2008). With large tracts of Africa already vulnerable and struggling to cope with recurrent floods and droughts compounded by a combination of poverty, conflict and HIV/AIDS; the impacts of climate change could be devastating for the continent (ICPAC, 2007).

In the Southern African Development Community (SADC), climate change is high on the agenda as was illustrated during the second SADC Multi Stakeholder Water Dialogue in Lesotho in May 2008. The workshop was aptly themed "Watering development in SADC: Rising above the Climate Change threat towards Security". Without downplaying the relevance and importance of softer options, such as demand management, for mitigating the impacts of climate change on water resources, the workshop focussed on the role of infrastructural development such as the construction of dams, and financing thereof. It was concluded that the SADC region has a huge potential, of which only a very small proportion has been tapped, for the development of infrastructure to mitigate (in combination with other measures) the impacts of climate change on water resources. It was acknowledged during the workshop that there is an existing water infrastructure, of which its relevance, efficacy and management in the context of climate change needs to be ascertained.

The World Commission on Dams (WCD) and the United Nations Environmental Programme (UNEP) commissioned a study to investigate the linkages between climate change and reservoirs. Climate change is likely to affect dam safety, reservoir yield and reliability, reservoir operation, as well as reservoir sedimentation and water quality. The study concluded that;

- climate change has the potential to significantly affect hydrological regimes to the point where they may produce conditions outside those for which dams are designed and operated;
- the impact of climate change on reservoir reliability depends very much on the characteristics of the reservoir;
- the impact of climate change on a reservoir may be very significantly affected by other pressures facing the reservoir, including changed demands and altered management objectives (Arnell et al., 2000).

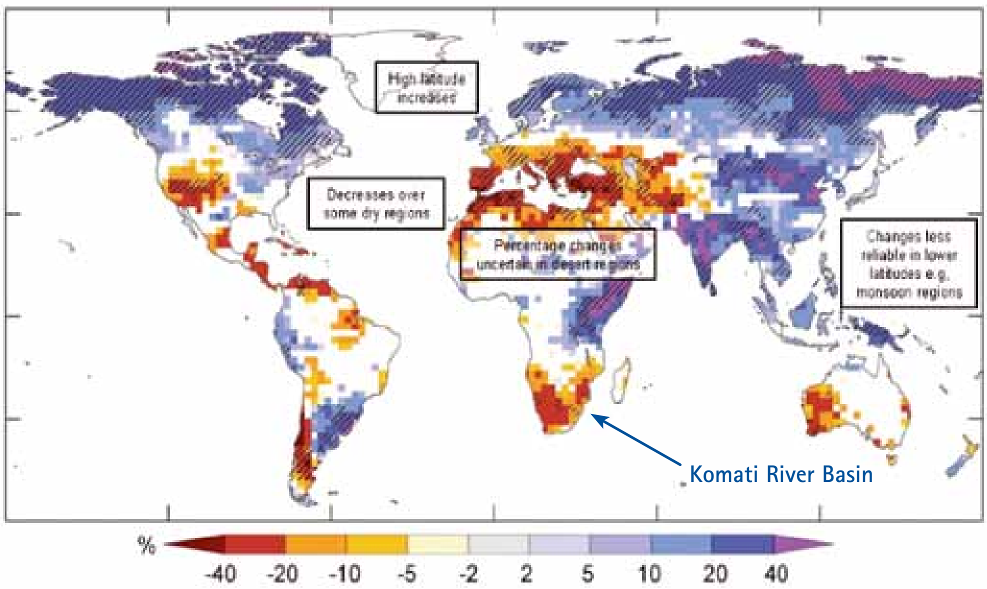


Figure 6.1: Projections and model consistency of relative changes in run-off by the end of the 21st century

The following sections discuss the strategies and actions employed by the Komati Basin Water Authority (KOBWA) to adapt the management of the water infrastructure, especially reservoirs, in relation to the ways by which reservoirs will be affected by climate change.

3. About KOBWA

The Komati Basin Water Authority (KOBWA) is a bi-national company formed in 1993 through the treaty on the Development and Utilisation of the Water Resources of the Komati River Basin, signed in 1992 between the Kingdom of Swaziland and the Republic of South Africa (Joint Water Commission, 1992). The purpose of KOBWA is to implement Phase 1 of the Komati River Basin Development Project (KRBDP), which comprises of the design, construction, operation and maintenance of Driekoppies Dam on the Lomati River in South Africa and Maguga Dam on the Komati River in Swaziland (Figure 6.2). The economy of the Komati Basin is largely commercial agriculture-based with thriving sugar cane, citrus, and forestry plantations and secondary industry consisting of sugar and timber/saw mills. Another important water usage is thermal power cooling through inter-basin transfers to the coal-rich belt in the Eastern Highlands of South Africa.

Figure 6.2: Map of the Komati Basin Development Project. (Source: Joint Water Commission, 1992)

The Komati River Basin has a low Gross Domestic Product. Water usage by agricultural activity was estimated to be about 69% of the total water consumption and rising. Existing infrastructure could not harvest sufficient amounts of water to reliably support the economic activities in the basin. This led to chronic water shortages due to natural variability, which is compounded by the escalating demand. Therefore, the KRBDP came to being as a joint effort between South Africa and Swaziland to develop and manage the water resources of the Komati Basin in order to augment water supplies and provide relief for the water shortages. The project was also aimed at injecting pace to economic growth in the region through new and existing small to medium-scale water-based poverty reduction initiatives in the agriculture and tourism sectors. The first phase of the project (design and construction) reached completion in 2002; hence, KOBWA is now operating and maintaining the developed infrastructure. Operating and maintaining the infrastructure entails ensuring dam safety; developing and implementing, inter alia, operating and accounting systems and procedures to enable efficient delivery of water to users; developing and maintaining a maintenance programme for the water infrastructure; as well as undertaking water resources and aquatic ecosystem monitoring.

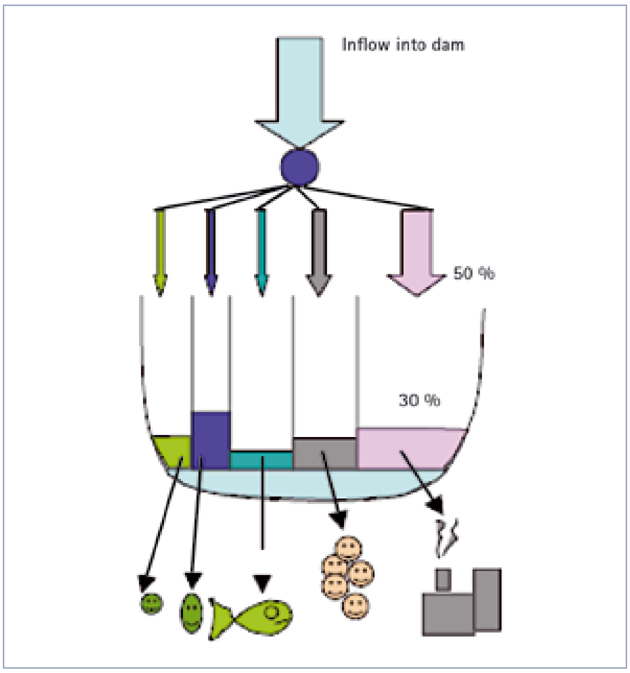


Figure 6.3: Re-evaluation of Water Allocation Policies: Fractional Water Allocation and Reservoir Capacity Sharing versus Tradition Water Allocation Criteria (use it or loose it)

4. Institutional Arrangement

As an implementing agency for the partner states, KOBWA is the core of the institutional arrangement (Figure 6.4) that promotes cooperative management between South Africa and Swaziland in relation to water resources of the Komati River Basin. The two countries established a Joint Water Commission (JWC), an advisory body to the respective governments on water resources of mutual interest. KOBWA is managed by a Board of Directors. The Komati Joint Operations Forum (KJOF) is a stakeholder representative forum that was created to assist KOBWA in operating the dams. It is comprised of representatives of the water users and officials from the water departments of both countries.

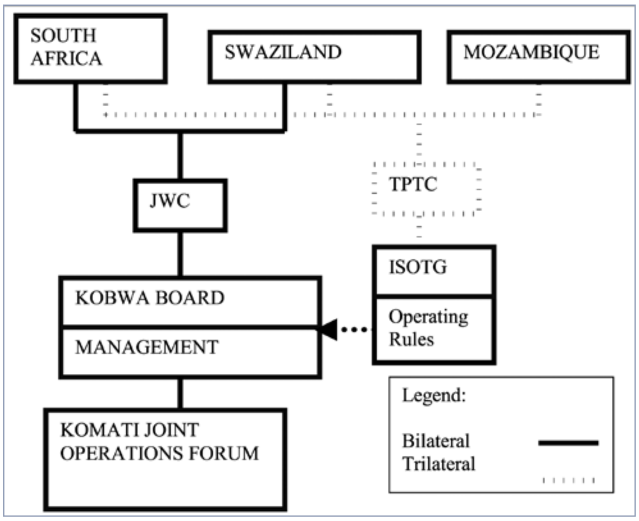


Figure 6.4: Institutional arrangement in the Komati Basin. (Source: Dlamini et al., 2007)

5. Climate Change Considerations in the Komati Basin

There is a growing consensus, at least in the scientific community, about the likelihood of long-term average global climate change as a consequence of global warming (IPCC, 2001). Recent studies in southern Africa (Hewitson et al., 2005; Engelbrecht, 2005; Warburton et al., 2005) are in agreement with global studies about the broad regional trends of change of precipitation and temperature due to climate change. Global Circulation Model (GCM) simulations of the south eastern subcontinent, in which the Komati Basin is located, show that it will experience an increase in rainfall in the early summer within the context of the future climate (Engelbrecht, 2005). Schulze and Dlamini (2005) note that inflows into the Mnjoli Dam, a reservoir in the Mbuluzi catchment that is adjacent to the Komati, are likely to decrease by up to 40 % due only to climate change if everything else including demand was to remain unchanged. Research work by Rouault et al. (2008), shown in Figure 6.5, suggests that droughts may become more severe, longer and cover wider areas. While this brief review does not provide irrefutable evidence of the occurrence of climate change in the Komati Basin, it does present challenging issues to KOBWA in relation to the implementation of the KRBDP. Whether or not this is a result of climate change, the conditions (i.e. climate, hydrological, economic, political and environmental) have changed from what they were at the time of conceptualising the project. This means that the management of the project, especially the infrastructure, must be adaptable in order to ensure the realisation of the broader aims of the project despite the changed or unanticipated conditions upon project completion. KOBWA has set-up and continuously modified its operation and management philosophy in order to cope with variable climatic conditions. Most of the measures are not tailored for climate change per se, but they reflect the consciousness of the need for preparedness to adapt the management in order to address unforeseen changes in the operating environment, including those due to climate change. Dams form an integral part of such a preparedness strategy. The Incomati Basin, of which the Komati is a sub-basin, has been developed extensively in terms of water storage infrastructure (Figures 6.1, 6.6 and 6.7) and still has more untapped potential. The so-called hard solutions such as infrastructure development are only a part of the broader strategy which includes softer options such as promoting demand management, conservation and higher water use efficiency, as well as investing in early detection and warning, preparedness planning and real-time system operation. Moreover, these strategies are not solely driven by KOBWA, but inherently by the partner states within the ambit of cooperative management of the shared water resources. Therefore, KOBWA adaptations are primarily in managing the project (system operation and enhancements) in pursuance of the broad economic, social and political goals of the project.

The following sections discuss the adaptive strategies adopted by KOBWA to cope with change and their relevance in the context of climate change.

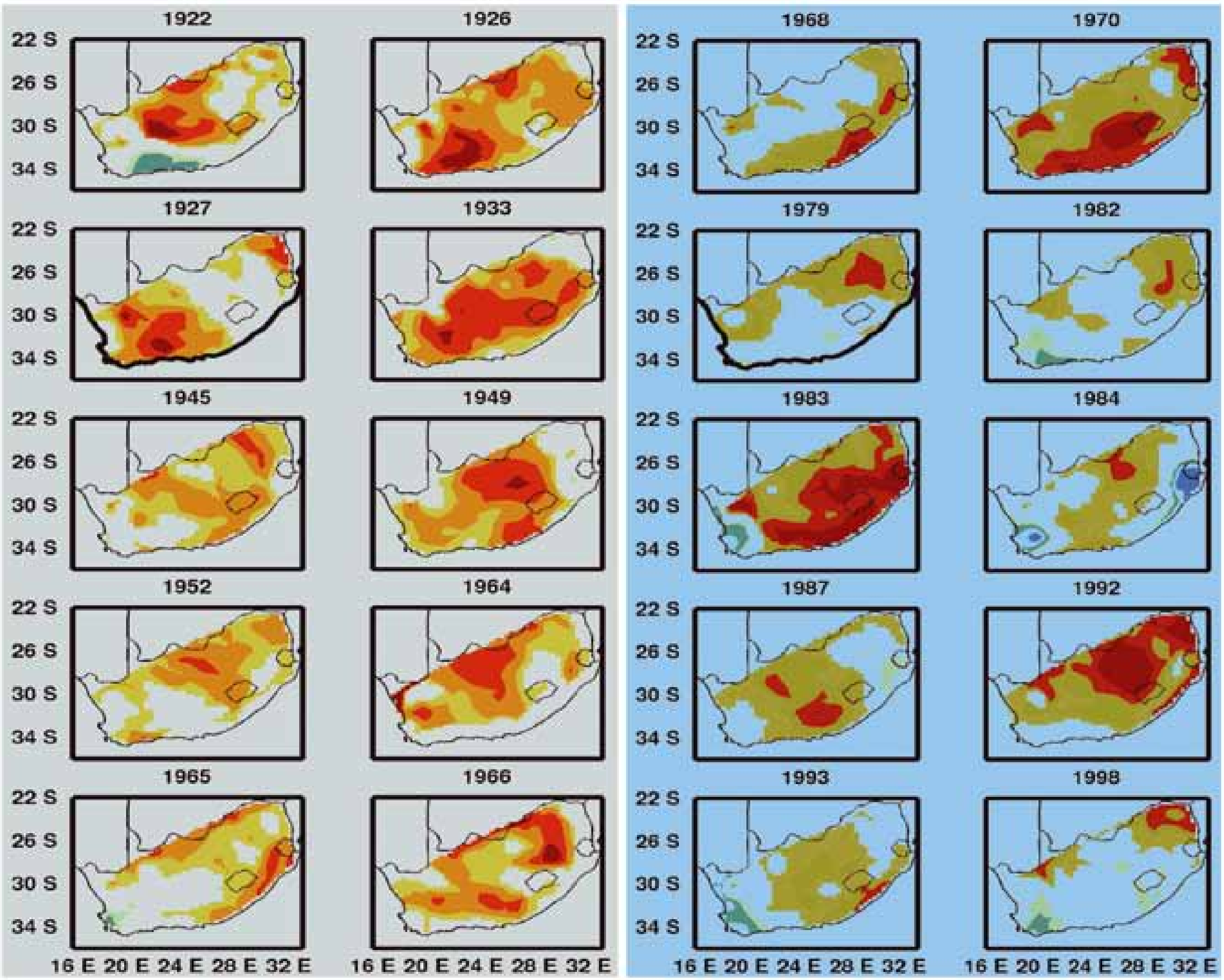


Figure 6.5: Spatial extent of the 6-month standardised precipitation index (SPI) for the worst dry years since 1922. Legend: brown - extremely dry; red – severely dry; orange – moderately dry; yellow – dry (near normal); dark blue – extremely wet; light blue – very wet; dark green - moderately wet; green – wet (near normal). Source: Rouault et al., 2008.

Dam developments in the Incomati Basin

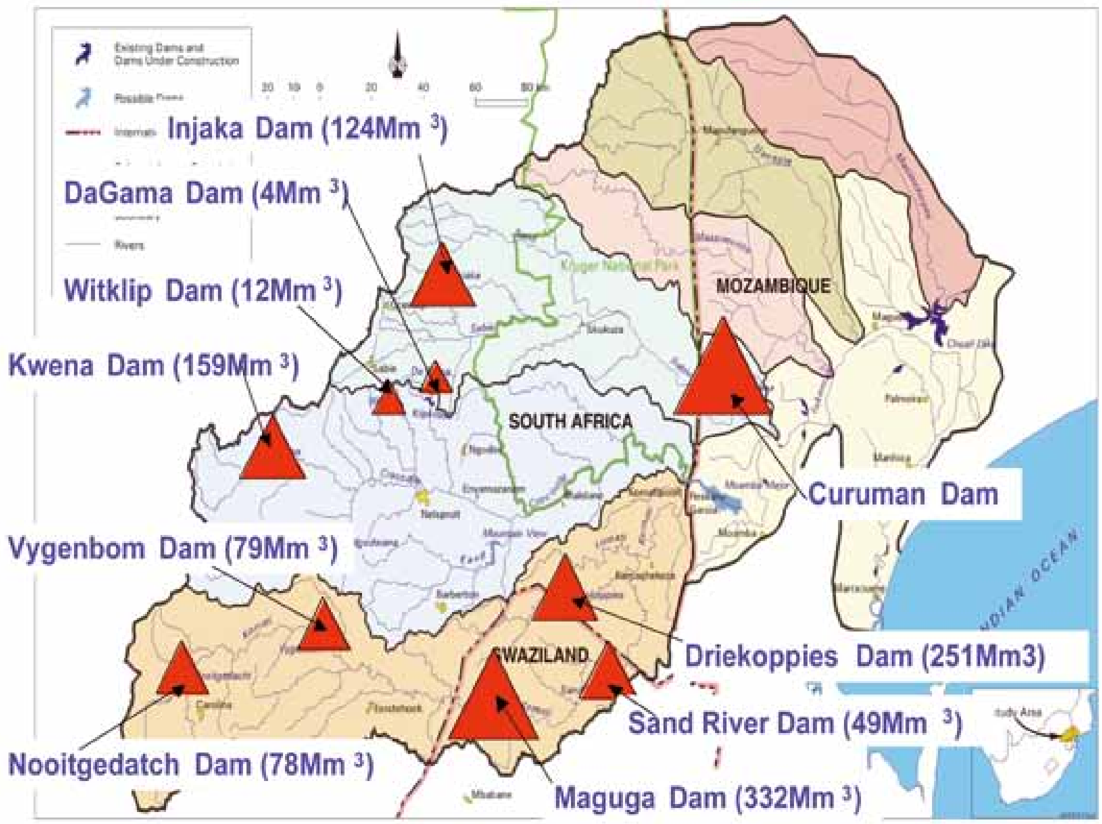


Figure 6.6: Water storage infrastructure in the Incomati Basin (After JIBS, 2001)

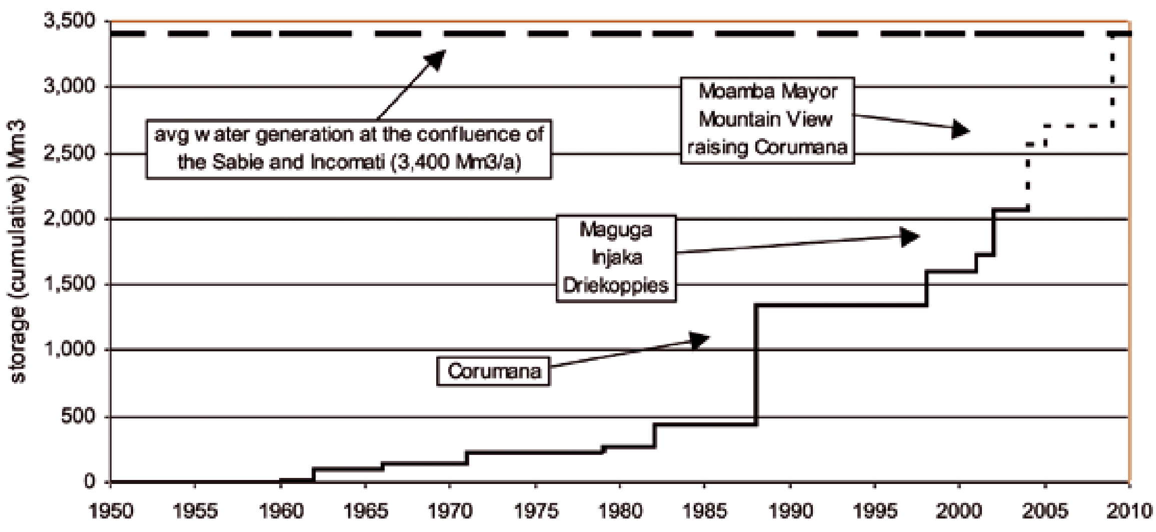


Figure 6.7: Cumulative volume of storage infrastructure over time in the Incomati Basin. (Source: Carmo Vaz and van der Zaag, 2003)

6. Adaptation Strategies and Actions for Managing of Reservoirs in the Komati River Basin

The climate and hydrology of the Komati River Basin is characterized by long periodic droughts that are often broken by the sudden occurrence of a series of exceptionally high rainfall and stream flows (Alexander, 2002). As an agro-based economy the effects of climate change in the Komati River Basin have been felt mostly in the agriculture sector: The pillar of the basin economy. Dams have been built to mitigate the effects of both increased demand for water and prolonged droughts that are broken by floods of increasing magnitudes. Governments in the Komati River Basin continually re-evaluate legal, technical and economic policies and procedures for managing water resources in light of climate change (Hornby, 2008). These policies are interlinked and should not be dealt with in isolation. In addition, the continuous re-evaluation of these policies and procedures should be standard good practice in water resources management, irrespective of their role in enhancing adaptation to climate change.

6.1 Economic Policies and Procedures

Initially most of the dams in the Komati River Basin were built with the aim of increasing commercial agriculture and energy production. However, over the years, climatic variations have made most of the population of the basin who rely on subsistence agriculture vulnerable to crop failure. Increases of droughts have also seen the commercial agriculture sector adopting farming strategies that resulted in reduced employment. All these effects resulted in increased vulnerability to poverty especially to the previously marginalized populations in South Africa as well as the rural populations in Swaziland. Prolonged droughts also meant that subsistence agriculture that relied on rainfall for crop production was no longer sustainable. Crop failure became prevalent as rainfall seasons shifted and became shorter. For example, the years 2006-2007 and 2008-2009 had good average rainfall; however, the rains came later in the growing season – which resulted in massive crop failure. These climate change effects forced the Governments to consider strategies to combat poverty in the basin. In the last couple of years dam development policies shifted from large scale commercial agriculture towards small scale projects aimed at poverty alleviation through energy, water supply and sanitation and food production. Phase 1 of the Komati River Basin Development Project comprising the Maguga and Driekoppies Dams is an example of such a project whose initial aim of commercial agriculture has been changed to focus on poverty alleviation through small-scale commercial irrigation that directly addresses unemployment and increase food production.

Changes in dam development policy resulting from climate change impacts have a bearing on project viability. At the feasibility study stage the Government of Swaziland considered developing the Maguga Dam for large-scale commercial agriculture (Alexander Gibb and Partners, 1992). This showed a viable project from a financial point of view. However, at the planning stage it became obvious that large-scale commercial agriculture would exclude vulnerable communities subjected to climate change impacts such as droughts. The policy was later changed at implementation towards developing the Maguga Dam for small-scale commercial agriculture, energy production and water supply and sanitation for rural communities on communal land (Collingath Consulting Economists, 2004). New economic evaluation procedures were adopted that did not only consider the projects financial viability but also other social considerations such as poverty. Currently dam development economic policies are reviewed constantly to align them to take climate change impacts into account.

Dams in Phase 1 of the Komati River Basin Development Project were sized and built using available hydrologic information. They are also operated using past hydrologic records to guide decisions. Irrigation systems were designed using historic information on temperature, water availability and soil water requirements. For example, water requirement analysis took into account effective rainfall for irrigation based on historic data. Water in the reservoirs was meant to only supplement the shortfall between effective rainfall and the crop water requirement. The prolonged droughts in recent years (1981-1984, 1992-1996 and 2001-2004) have resulted in an increase in water requirements requiring more water to be supplied from the reservoirs. This climate change impact alters the project viability in that the areas earmarked for development have to be reduced as the risk of supply failure increased. This means that water is now a limiting factor to full project development. Financiers (mostly local banks) are increasingly worried about the fact that water is becoming a limiting factor and they are reluctant to finance irrigation projects (SWADE, 2004). Swaziland is now actively encouraging farmers to adopt water conservation and demand management strategies to combat the decline in project economics. Amongst the water conservation and demand management strategies is the use of more water efficient irrigation methodologies as well as a conversion to less water consumptive crops such as cassava and sweet potatoes (NEPAD, 2005).

Climate variation in the Komati River Basin delayed the filling of the Maguga Dam. On average, it had been projected that the Maguga Dam project would fill up within the first two years of impoundment. Farmers in South Africa reached full development in anticipation of water from the project before dam construction completion. The Swaziland Government established the Swaziland Komati Project Enterprise (SKPE) now Swaziland Water and Agriculture Project Enterprise (SWADE) to assist farmers in the Komati Downstream Development Project to develop irrigation in anticipation of water from the Maguga Dam. Completion of the Maguga Dam Completion then coincided with one of the longest droughts in the Komati River Basin (2001 – 2004). It took almost four years for the Maguga Dam to fill-up. Meanwhile farmers (mainly smal-scale farmers) had raised loans and prepared their land and ready for planting. The delayed production due to lack of water as a result of the prolonged drought put a number of farmers in huge financial difficulties. Loan repayments had to be renegotiated to assist farmers (SWADE, 2004). Risk based project economic criteria has now been initiated to take into account the effects of climate variations on project economics. There are a number of risk-based economic models on the market, including classical project economic sensitivity analysis models. The latest risk-based models, however, consider the risk to the project economic viability resulting from varying legal, political technical and economic factors. Cost-benefit analysis, social accounting matrices, value chains, climate change prediction models, water allocation models form a suit of project risk models where the outcome may be expressed as an economic value. A classical example of these was the modelling of the economic impact of the filling of Maguga Dam (Alexander Gibb and Partners, 1992).

6.2 Systematic re-evaluation of Dam Design Criteria

Climate change is making dam construction expensive because larger spillways have to be considered to discharge large floods, while at the same time larger dam capacities have to be considered to store enough water to last through the severe and prolonged droughts. Droughts destroy natural vegetation and when large flood events occur they lead to massive soil erosion, which increases the siltation of dam. All these factors add cost to dam infrastructure. The Maguga Dam spillway was sized to accommodate a regional probable maximum flood of 15m3/s. This was a result of Cyclone Domoina floods of 1984. At the same time the capacity of Maguga Dam had to accommodate severe droughts such as the 1981–1984 and the 1992–1995 droughts. Because climate change causes the parameters used for dam design to change, it is important to constantly review these parameters in the light of new hydrometeorological information. In the case of the Komati River Basin, dam safety legislation is continuously reviewed and one of the important aspects of the review is the periodic review of dam safety procedures and assessments. The International Commission on Large Dams (ICOLD) provides most of the guidelines for dam safety (ICOLD, 2006). These are adapted for local conditions by the South Africa Commission on Large Dams (SANCOLD) and its affiliates in neighbouring countries (SANCOLD, 2008). A risk-based approach to the design of dams and dam safety evaluation procedures has been adopted to account for climatic variations. Dam surveillance is also constantly reviewed to provide timely information on dam behaviour resulting from climate change impacts. More and more dam surveillance monitoring uses real-time information so that any deficiencies or occurrences are detected on time.

6.3 Systematic re-evaluation of contingency and emergency preparedness plans

In the Komati River Basin floods are getting larger and more frequent. No one knows when and how large the next flood will be especially under climatic change. It is therefore important to put in place adaptation strategies in case these floods cause serious dam infrastructure damage or failure. One way to prepare for this eventuality is to improve emergency preparedness procedures. Emanating from the United Nations declaring 1990 to 2000 as the International Decade of Natural Disaster Reduction and the reality of the 2000 floods in Southern Africa, the riparian countries in the Komati River Basin have increased measures regarding flood emergency disaster preparedness. Each of the countries has enacted legislation on disaster preparedness but have also gone further in the spirit of the Southern African Development Community (SADC) and the SADC Protocol on Shared Watercourses to put in place mechanism at basin level to alert and assist each other during food emergencies. For dams, two levels of emergency preparedness plans have been developed in the Komati River Basin. The first is an infrastructure plan that deals with detection and notification on emerging conditions at the dam that could lead to disaster. The second deals with community preparedness in the event a disaster occurs. This covers warning, evacuation and mitigation. A risk-based approach to the design of emergency preparedness plans has been adopted to account for climatic variations. Regular exercises are conducted to exercise the flood emergency preparedness plan.

6.4 Systematic re-examination of Dam and System Operating Rules

Dams require operating rules through which they will be operated in order to achieve their intended purpose. However these set of operating rules are based on given information which is usually historical in nature. Climate change can make these rules obsolete or ineffective. The operating rules for the Dams in the Komati River Basin cover aspects such as the hydrometric network required for system monitoring, international cross-border flows, water year, hydropower operation, water allocation system and the decision support systems to be used.

The operating rules for the Komati system define a hydrological year beginning on April 1, and ending in March of the following year. This water year is intended to start at the end of the rainy season where all the rainfall has occurred and the system short-term yield can be defined with certainty. In the last few years the rainfall pattern is such that most of the rain occurs in the month of April. This has resulted in a re-think of the water year prescribed in the operating rules and may necessitate a further review.

6.5 Re-evaluation of water allocation policies

The water allocation used in the Komati River Basin is a hybrid of the standard water allocation methodology, the fractional water allocation and reservoir capacity sharing approach (Dlamini et al., 2007). The water allocation defines two types of water; high assurance and low assurance. High assurance water, which is available 98% of the time, is primarily intended for strategic purposes such as domestic and industrial uses. Low assurance water, 70% of which is available 98% of the time and the remaining 30% is available 80% of the time, is intended for irrigation uses. Water is allocated on an annual volumetric basis.

Water that is not utilized in one year by a user can be stored for the following year, if there is storage space available in the reservoir. This type of water allocation, together with the unusually high assurance of supply is aimed at cushioning vulnerable users, such as smal-scale farmers, farmers from hydrological and climatic effects that maybe exasperated by climate change. A further advantage of this type of water allocation is that it allows water users to be directly responsible for managing their allocated water, thereby avoiding the transfer of risk from one user to another and from one sector to another. Users request the water allocated to them as and when they

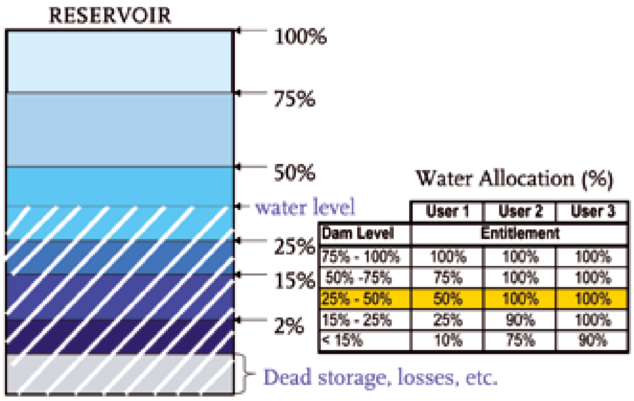


Figure 6.8: Traditional reservoir water allocation method

Water allocations and water usage under phase 1 of the Komati River Basin Development Project (Total annual water allocations (million m^3)

	South Africa			Swaziland		
Year	**Allocation**	**Usage**	**Savings**	**Allocation**	**Usage**	**Savings**
2002/2003	236.6	244.8	-8.2	215.7	219.6	-3.9
2003/2004	97.4	112.9	-15.5	129.3	127.3	2.0
2004/2005	177.6	150.9	26.7	205.5	189.6	15.9
2005/2006	210.1	180.6	29.5	175.0	160.4	14.6
2006/2007	285.4	264.1	21.3	243.3	190.1	53.2

NB: The allocations have been adjusted from the Treaty allocation to cater for water supply to Mozambique and exclude water allocated above the Dams and Lomati Tributaries.

Table 6.1: Water allocations and water usage under phase 1 of the Komati River Basin development Project (total annual water allocation in million m3)

need it to minimize wastage of water. Since the application of this water allocation method in 2002, conflicts amongst users has diminished and greater water savings have been realized as shown in Table 1.

6.6 Application of Risk-Based Decision Support Systems

Decision Support Systems are used to determine the capacity of a reservoir as well as its operation rules. Most decision support systems utilize historic hydrometeorological information. Over time, critical parameters used in dam design and reservoir sizing that are based on historic information could change. For example, the critical period is one of the important parameters in the sizing of dams. As more severe hydrometeorological occur, the critical period may change. To minimize the risk of changes in key design parameters, stochastic models are used to simulate a range of possible scenarios. However, most stochastic models do not incorporate climate change effects. In the Komati River Basin, the decision support system commonly used for reservoir sizing and to develop dam operating rules is the Water Resources Yield Model (WRYM) developed by Acres International (BKS/SSO, 1987) for the Department of Water Affairs and Forestry in South Africa. This model was developed for the Vaal River System where water in storage comprises a large proportion of total water available. This model was inadequate in the Komati River Basin where unregulated flow constitutes a larger proportion of total water availability.

A new risk-based decision support model suitable for the Komati River Basin had to be developed. The Rationing Model that takes into account the effects of antecedent conditions often imposed by climate change was developed for operating the Komati River Basin (Sparks et al., 2003). Currently, new decision support models such as the Mike Basin™, are being tested and improved. One of the improvements being undertaken and tested is to have the stochastic component of the Mike Basin™ carried out on rainfall instead of river flow and using a rainfall–runoff routine to simulate reservoir inflow. The Mike Basin™ model allows for the use of climatic data such as rainfall and evaporation in addition to streamflow data. Future scenarios of climatic events can be obtained from global circulation models that generate a range of possible rainfall and evaporation scenarios that can be used to predict the impact of climate change on streamflow. The stochastic modelling can be directly carried out on climatic variables such as rainfall generated by global circulation models. This enhances the chance of predicting the impact of climate change on water resources and can assist infrastructure managers to adapt to possible climate change impacts.

6.7 Real-Time System Operation

In South Africa only 60% of the available river flow is controllable via reservoirs, as shown in Figure 6.9 (Mwaka, 2007). The „lost „ proportion of river flow becomes even greater with climate change because reservoirs do not control all of the inflows. Real-time system operation is a strategy for managing reservoirs that enables the uncontrollable portion of river flow to be managed virtually. This can be done by monitoring real-time river flow conditions and only releasing water from storage in reservoirs to supplement the uncontrollable water in the system. This strategy minimizes losses and can achieve water conservation, forecast and pre-release to manage water quality, flood control and dam safety.

The Mike Flood Watch modelling environment is a decision support system to manage reservoirs in a changing environment (DHI, 2005). Real-time system operation requires an intensive and reliable real-time monitoring system and data acquisition as well as a well-developed institutional structure (fig 6.10). Although the real-time system operation is at its infancy stages, it is expected to be one of the most important tools to adapt reservoir management to climate change effects.

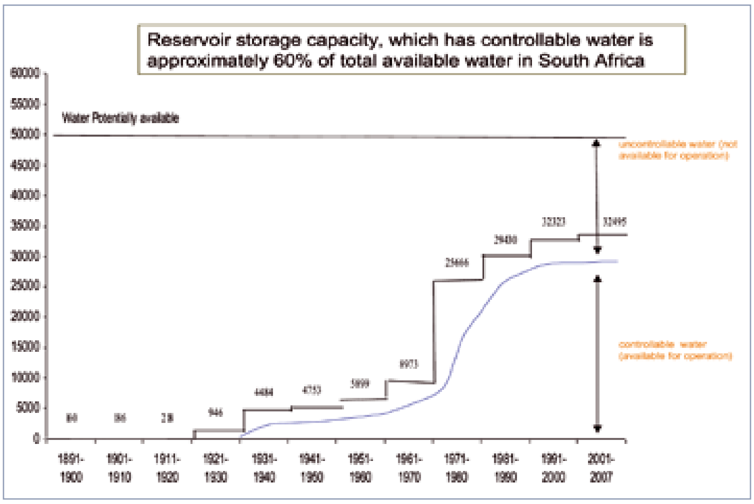


Figure 6.9: Controllable (storable in reservoirs) and uncontrollable water as percentages of total available water resources in South Africa (Mwaka, 2007)

A comprehensive review of system operating procedures is currently underway for the Komati River Basin to evaluate the effectiveness and efficiency of the current operating rules. As part of its output, the study will evaluate how climate change has affected the operational management of the Komati River Basin infrastructure as well recommend means to improve system operation in light of climate change.

Real time and model interaction

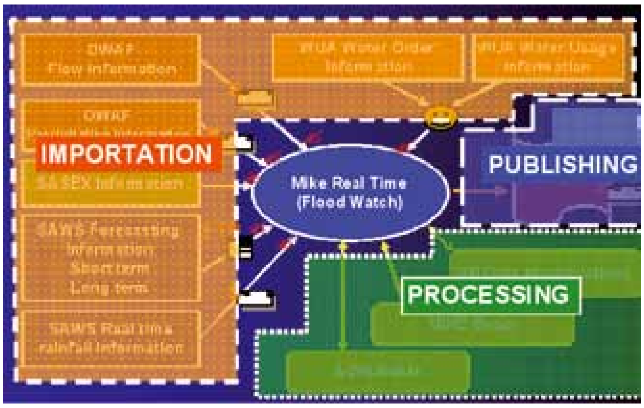


Figure 6.10: Real time system operation

6.8 Transboundary aspects of reservoir management

International agreements on the management of transboundary water resources, especially reservoir construction and management, take years to negotiate. Climate change makes the process even more difficult in that by the time the agreement is concluded the hydrometeorological parameters used in the agreement may have altered the situation. Negotiations between Swaziland and South Africa on Phase 1 of the Komati River Basin Development Project began in 1981 and were concluded in 1992. Mozambique could not be part of the negotiations due to internal civil strife. However, Swaziland and South Africa sought Mozambique's consent before signing the agreement. In 1991 the Pigg's Peak Agreement (TPTC, 1991) was signed where Mozambique gave its consent to the project subject to an interim minimum cross-border flow to Mozambique of 2 m3/s averaged over three days.

When the project commenced in 2002 it coincided with one of the longest droughts in the Komati River Basin. This made it increasingly difficult for Swaziland and South Africa to comply with the 2 m3/s agreed in Pigg's Peak in 1991. On several occasions Mozambique complained through the diplomatic channels that the agreement was being violated. The Pigg's Peak Agreement did not anticipate this climate change problem when it fixed the cross-border flow. However, the situation was anticipated by the broader Interim Inco-Maputo Agreement that was signed by the three countries at the World Summit on Sustainable Development in Johannesburg – South Africa (TIA, 2002). Article 10 of the Interim Inco-Maputo Agreement acknowledged the effects of climate change and made provision for a Task Team to be established to recommend flow regime modifications between the countries in cases of extreme droughts and floods. A multi-criteria risk-based decision analysis is therefore essential when drawing up international water agreements.

6.9 Ecological Water Requirement for Aquatic Ecosystems

Aquatic ecosystems provide goods and services that are essential for livelihoods, especially for the poor. Dams can alter aquatic ecosystems rendering them functionless in providing essential goods and services. Since the World Conference on Sustainable Development (UNCSD, 1992), the impact of dams on the environment has gained prominence. The World Commission on Dams published its report in 2000 (WCD, 2003). One of the key recommendations was that dams should provide water for the environment. Today, dams – old and new – must have environmental considerations in their operation. Climate change could alter the balance of scales in that dams that were built for a particular purpose in mind may be rendered functionless when environmental water is factored in.

Re-evaluation and monitoring of Ecological Water Requirement: Establish various scenarios for the supply of ecological water requirement scenarios

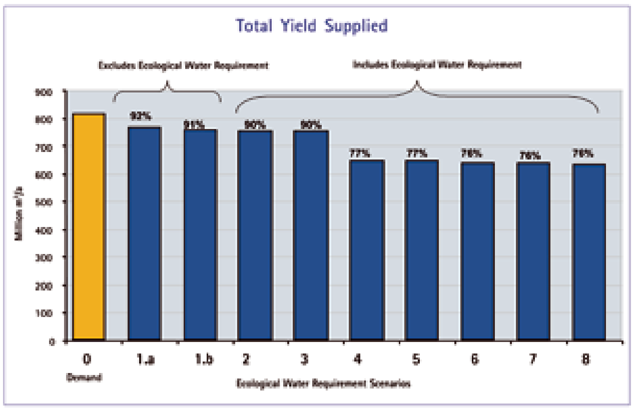


Figure 6.11: Total water supplied (in million m3/a) to users for various flow scenarios in the Komati River Basin (AfriDev, 2006)

In the Komati River Basin all of the dams were planned at a time when the environmental considerations were not taken into account. Unfortunately, today, water for the environment has moved to the top of the development agenda. South Africa and Swaziland as well as Mozambique, have water and environment legislation that requires dams to provide water for the environment as a priority. An environmental water requirement study of the Komati River Basin was carried out by South Africa in 2006 that also covered the Swaziland portion of the basin (AfriDev, 2006). Various environmental water requirement scenarios were considered and their socio-economic and environmental consequences evaluated. The study concluded that if the full environmental flow scenario is imposed, it would result in a serious reduction in utilizable water leading to massive job losses in the predominantly agro-based economy of the basin as well as a reduction in income for the poor and the basins gross domestic product. Figure 6.11 shows the effects of implementing the ecological reserve on water availability in the Komati River Basin. In a catchment that is already over allocated, the inclusion of an ecological water requirement would aggrevate the situation by reducing water availability by a further 24%.

Climate change in the Komati River Basin means longer and more severe drought periods that are often terminated by large floods. Such a scenario would result in larger amounts of water for the environment from the reservoirs to augment river flows in drought years and also larger dam sizes to mitigate floods. An adaptive management approach has been adopted by the riparian states for the management of reservoirs in respect of climate change. Swaziland and South Africa are currently carrying out a basin wide study of the ecological water requirement for the Komati River Basin. This study is aimed at forging policies and strategies to provide water for the aquatic ecosystem using the current infrastructure (reservoirs) in a manner so as not to adversely impact on the socioeconomy of the basin.

6.10 Water Conservation and Demand Management

Dams can only address the supply side of the water management equation. As already stated, dams are very expensive to build and manage, and have serious social and environmental costs. Climate change can only aggravate the already bleak situation of dams. Water conservation and demand management is one the critical strategies to help adapt reservoir management for climate change. Domestic and industrial water supply only accounts for a small component of the total water utilized in the Komati River Basin. To reduce water consumption for thermal power cooling, South Africa is actively converting some of its thermal power plants to dry cooling. Municipalities are ensuring that water losses are reduced as well as encouraging households to practice water serving technologies (e.g. dual flush toilets) and practices (e.g. use of showers instead of bath tubs). Consumers are also being encourage to make use of rainwater harvesting technologies.

Agriculture uses the major portion of water in the Komati River Basin. This is an area where great savings can be achieved through water conservation and demand management. Already there is a move towards more efficient irrigation methods such as subsurface drip and centre pivot. Irrigation scheduling is a common practice to help ensure that irrigation is only applied when it is required. The Komati River Basin is one of the leading River Basins in Southern Africa when it comes to abstraction measurement as a means for water conservation and demand measurement. Abstraction measurement is a legal requirement in both South Africa and Swaziland. Power supply problems have led to cooperations between the energy and irrigation sectors in the Komati River Basin; namely, electricity companies are collaborating succesfully with irrigators through the supply of water abstraction measuring devices. Incentives for pumping (irrigating) during off peak power demand times are also under discussion. The Komati Basin Water Authority is currently undertaking a basin-wide study that includes the investigation of water conservation and demand management strategies to maximize system efficiency.

6.11 Institutional adaptation

A strong and effective institutional structure is a central strategy to help adapt reservoir management to climate change. Water legislation in both South Africa and Swaziland has recognized the importance of decentralizing decision making related to the management of water resources. While the ownership of water is vested in the state, according to the National Water Act (RSA, 1998), the management of water resources is delegated down to those who use the water. In South Africa Catchment Management Agencies (CMAs), Catchment Councils (CAs), Water Users Associations (WUAs) and Irrigation Boards (IBs) are empowered to make decisions on water use. Similarly in Swaziland River Basin Authorities (RBAs), Irrigation Boards (IBs), Irrigation Districts (IDs) and Water Users Associations (WUAs) have been established with similar aims (fig 6.12).

At a transboundary level, article 3(3) of the Southern Africa Development Community Protocol on Shared Watercourses (SADC, 2000) encourages member states to establish transboundary watercourse institutions.

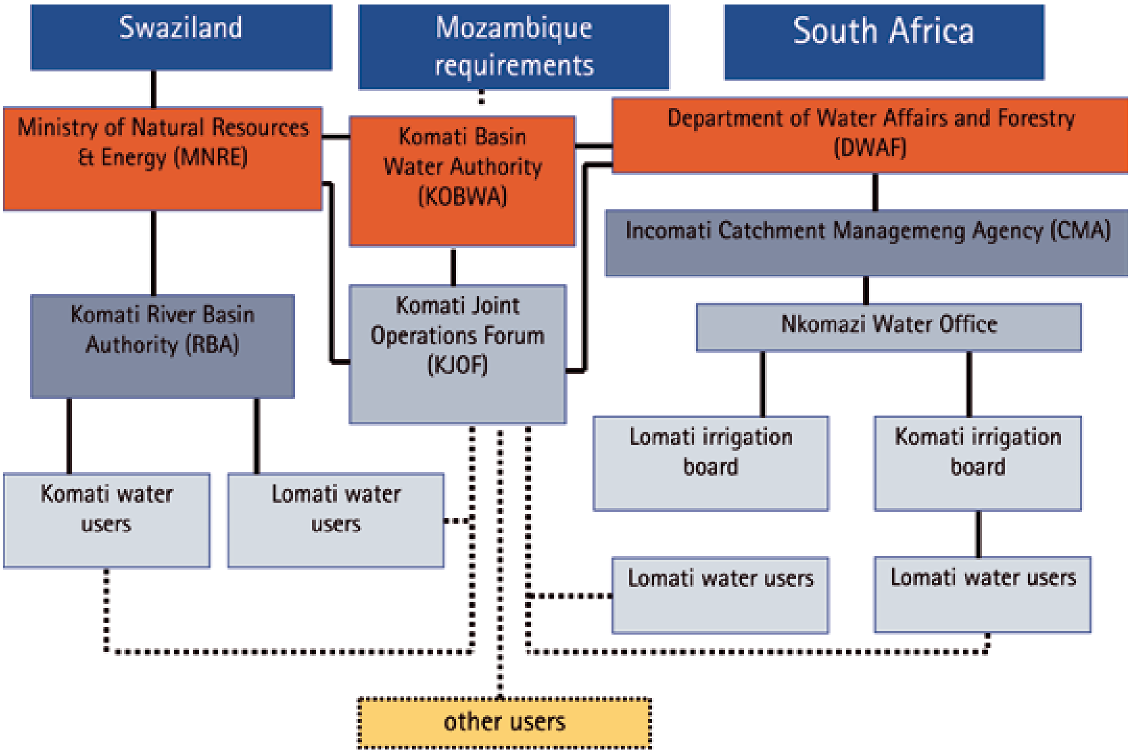


Figure 6.12: Grass roots water management structure (Komati Joint Operations Forum)

7. Conclusions

This paper discussed strategies and actions employed by the Komati Basin Water Authority (KOBWA) to adapt the management of the water infrastructure, especially reservoirs, in relation to climate change. The strategies and actions for adapting the management of reservoirs for climate change in the Komati River Basin include a re-evaluation of legal, technical and economic policies and procedures for managing water resources in light of climate variations. For reservoirs in particular, it involves a systematic re-examination of engineering design criteria, operating rules, contingency and emergency preparedness plans, as well as water allocation policies. Water demand management and institutional adaptation have become a major component in the management of reservoirs to help increase system flexibility and resilience to climatic variations. While there is capacity for structural measures to combat climate change in Komati River Basin, such as the construction of more dams, a greater emphasis is placed on non-structural measures such as demand management that are less costly and more efficient and effective. The strategies and action for adapting reservoir management in light of climate change applied in the Komati River Basin can be applied elsewhere in the world. They should be considered for good water resources practices regardless of climate change.

References

AfriDev. 2006. Komati Catchment Ecological Water Requirements Study: Main Report. Department of Water Affairs and Forestry, Pretoria, South Africa.

Alexander, W. J. R. 2002. Climate change – the missing link. Science in Africa. http://www.scienceinafrica.co.za/2002/september/climate.htm [Accessed 9 July 2008]

Arnell, N. and Hulme, M. 2000. Implications of Climate Change for Large Dams and their Management. WCD Thematic Review II.2: Environmental Issues. World Commission on Dams Secretariat, Cape Town, South Africa.

BKS/SSO. 1987. Vaal River System Analysis – Analysis Procedure Manual: Addendum A: ARSP user guide. Department of Water Affairs. Report PC 000/00/6986. Pretoria, South Africa.

Conningarth Consulting Economists, 2004. Study to Address Key Issues Sorrounding the Realisation of the Komati River Basin Development. Ministry of Natural Resources and Energy, Mbabane, Swaziland.

DHI. 2005. MIKE FLOOD WATCH: Decision support system for real-time flow forecasting. http://www.dhigroup.com/Software/WaterResources/MIKEFLOODWATCH.aspx [accessed 12 July 2008]

Dlamini, E. M., Dhlamini, S. M. and Mthimkhulu, S. Fractional water allocation and reservoir capacity sharing concepts: A adaptation for the Komati Basin. Physics and Chemistry of the Earth (32) 1275 – 1284.

Engelbrecht, F. 2005. Simulations of climate and climate change over southern and tropical africa with the conformal-cubic atmospheric model. In: Schulze, R. (ed). Climate Change and Southern Africa. WRC Report 1430/1/05. Water Research Commission, Pretoria, South Africa.

Hewitson, B., Tadross, M. and Jack, C. 2005. Scenarios developed with empirical and regional climate model-based downscaling. In: Schulze, R. (ed). Climate Change and Southern Africa. WRC Report 1430/1/05. Water Research Commission, Pretoria, South Africa.

Hornby, L. 2008. Climate change hit SA crops. Daily News article. http://www.dailynews.co.za/?fSectionId=3532&fArticleId=nw20080706152357245C555260 [accessed 6 July 2008]

ICOLD. 2006. http://www.icold-cigb.net/ [accessed 8 July 2008]

ICPAC. 2007. Climate Change and Human Development in Africa: Assessing the Risks and Vulnerability of Climate Change in Kenya, Malawi and Ethiopia. Human Development Report 2007/2008 (Draft). IGAD Climate Prediction and Applications Centre, United Nations Development Programme, United Nations, New York, USA.

IPCC. 2001. Climate Change 2001: Scientific Basis. Intergovernmental Panel on Climate Change, World Meteorological Organisation, WMO, Geneva, Switzerland. Also available at http://www.ipcc.ch/ [Accessed 13 February, 2005].

JIBS, 2001. Joint Inkomati Basin Study Phase 2. Consultec consoltores associados in association with BKS Acres Consulting Engineer. Department of Water Affairs, Mbabane Swaziland.

Joint Water Commission, 1992. Treaty on the development and utilization of the water resources of the Komati River Basin. Joint Water Commission, Mbabane Swaziland.

M. Rouault, C. J. R. Reason, N. Vigaud, A. Mavume and N. Fauchereau, 2008. Hydroclimatic Variation over Southern Africa At Intra-Annual And Inter-Annual Time Scales With Special Reference to the Role of the Oceans. WRC Report No 1476/1/08. Water Research Council, Pretoria, South Africa.

Mwaka, B. 2007. Real-time system operation for water resources management: A PowerPoint presentation for the ICOLD Short Course. CSIR, Pretoria, South Africa.

NEPAD. 2005. Government of the Kingdom of Swaziland: Support to NEPAD - CAAP Bankable Investment Project Profile. TCP/SWA/2910 (I) (NEPAD Ref. 05/19 E). NEPAD Secretariat, Midrand, Johannesburg, South Africa.

RSA 1998. The National Water Act. RSA Government Gazette 36 of 1998. Cape Town, RSA.

SADC. 2000. SADC Protocol on Shared Watercourses. SADC Secretariat, Gaborone, Botswana.

SANCOLD. 2008. Background. http://www.sancold.org.za/ [accessed 8 July 2008]

Schulze, R. and Dlamini, D. 2005. Potential impacts of a hypothetical, but plausible, climate change scenario on within-country reservoir management for irrigation, and out-of-country flow obligations in the Mbuluzi Catchment, Swaziland. In: Schulze, R. (ed). Climate Change and Southern Africa. WRC Report 1430/1/05. Water Research Commission, Pretoria, South Africa.

Sir Alexander Gibb and Partners. 1992. Review and Feasibility Study for Komati River Basin Development within Swaziland: Feasibility Report. Ministry of Natural Resources and Energy, Mbabane, Swaziland.

Sparks, A., Pegram, G. and Dlamini, E. 2003. Rationing Model: The development of a tool to help managers visualize the impacts of rationing and other decisions. Proceedings of the Eleventh South African National Hydrology Symposium. University of Port Elizabeth, Port Elizabeth, South Africa.

SWADE. 2004. Report to the Joint Water Commission on the Komati Downstream Development Project. Joint Water Commission Secretariat, Piggs Peak, Swaziland.

TIA. 2002. Tripartite Interim Agreement between Mozambique, South Africa and Swaziland for Cooperation on the Protection and Sustainable Utilisation of the Water Resources of the Incomati and Maputo Watercourses. Johannesburg, South Africa.

TPTC. 1991. Pigg's Peak Agreement. Tripartite Permanent Technical Committee, Pigg's Peak, Swaziland.

UNCSD 1992. Agenda 21. United Nations Convention on Sustainable Development. United Nations, Geneva, Switzerland.

Vaz, A. C. and van der Zaag, P. 2003. Sharing the Incomati Water: cooperation and competition in the balance. In: UNESCO-IHP, Technical Document/PCCP series number 13. UNESCO, Paris.

Warburton, M., Schulze, R. and Maharaj, M. 2005. Is South Africa's temperature changing? An analysis of trends from daily records, 1950 – 2000. In: Schulze, R. (ed). Climate Change and Southern Africa. WRC Report 1430/1/05. Water Research Commission, Pretoria, South Africa.

WCD. 2003. Dams and Development. Earthscan Publications Ltd, London, UK.

Chapter 7

Infrastructure Management in a Changing Environment

The Case of Kariba Dam

By Michael James Tumbare. CEng., PhD. Zambezi River Authority, Zambia/Zimbabwe. Lusaka

Contents

1. Abstract

Purpose: The overall objective of this Case Study is to provide facts, analyses, findings and conclusions with recommendations focusing on adaptation strategies and measures necessary to mitigate the impacts of climate change in the management of the Kariba Dam and the water resources of Lake Kariba. Policy, planning, operations and investment strategies and measures will be highlighted and discussed.

Design/methodology/approach: The Case Study area is Lake Kariba and the Kariba Dam wall located in the mid-Zambezi River basin, between latitudes 16° and 17° south and longitudes 27° and 29° east. The data and information used for the Case Study is from records accumulated over the years by the Zambezi River Authority (ZRA) and its predecessors. The 2008 Zambezi River basin Integrated Water Resources Management Strategy and Implementation Plan Report will also be used as well as other literature reviews. ZRA data for Victoria Falls flows, Lake Kariba Lake levels and temperatures at Kariba Dam will be analysed to identify trends, cycles and changes that have occurred over the years. This will enable any effects or linkages of climate change to be identified and/or postulated. The history of occurrences of invasive weeds on Lake Kariba waters will also be traced and analysed pursuant to finding linkages with hydrological trends / cycles and climate change.

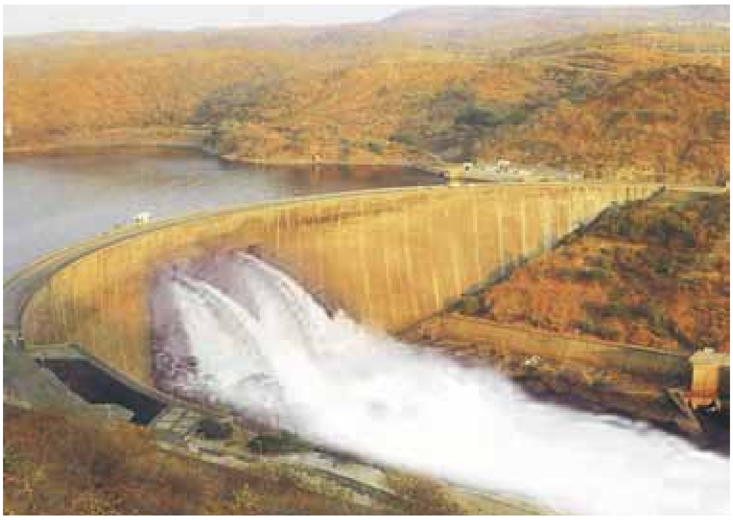


Figure 7.1: Kariba Dam

Findings: The Case Study highlights that the temperatures recorded at the Kariba Dam show a seemingly irreversible increase linked to reduced flows at the Victoria Falls resulting in lower inflows into Lake Kariba. The lowest recorded 5-year mean temperatures at Kariba are now on average higher by +2.8°C than those measured in the 1960s. Average inflows into Lake Kariba have also reduced over the same period. This has adverse effects in respect to hydropower generation, lake navigation and fish production.

Conclusions: The predicted impending low inflows into Lake Kariba have been highlighted in this Case Study as have the questions how the threats and challenges that would arise could be addressed/mitigated by the ZRA and other stakeholders to ensure the sustainable and continued economic operation of Lake Kariba and the Kariba Dam. The management solutions so far applied should continue to be monitored and evaluated on an annual basis with regard to the invasive weeds. This is a continuous process for ZRA staff augmented by its partners and other stakeholders which should help in finding adaptation solutions. However issues of global warming and climate change are international and require commitment and action at international level and by everyone on planet earth. The opinions and conclusions drawn in this Case Study are those of the author.

Keywords: Climate Change, Strategies, Management, Floods, Droughts, Stakeholders

2. Introduction

Lake Kariba was created in the late 1950's through the construction of a 125m high double curvature arch dam wall with a 627m crest length. At the time the Kariba Dam was officially commissioned for hydropower generation on 17th May 1960, Lake Kariba, with a water volume of 185km3, was the largest man-made water reservoir in the world.

Lake Kariba boasts a reservoir surface area of 5 580km^2, a reservoir length of 280km and width of 32km at its widest point at full supply level. Figure 7.2 shows Lake Kariba's upper and lower catchment areas which drain the five riparian states of: Angola, Namibia, Botswana, Zambia and Zimbabwe. This drainage area covers some 815 000km^2, or sixty percent of the whole Zambezi River basin area (Tumbare, 2000). ZRA has been tasked by the owners of the Kariba Dam, the Governments of the Republics of Zambia and Zimbabwe, to monitor, operate and maintain the Kariba Dam wall and manage the hydrology of Lake Kariba for hydropower generation and other stakeholder uses. ZRA has also been mandated to construct, as necessary, new hydropower dams on the mainstream Zambezi common to Zambia and Zimbabwe, and to make such recommendations to its owners as will ensure the effective and efficient use of the waters and other resources of the Zambezi. ZRA has thus over the years accumulated hydrological and environmental data and information pertaining to the Kariba Dam's catchment area and the Zambezi River in general, and operates thirteen telemetry stations pursuant to relevant data capture.

The Kariba Dam, which created Lake Kariba in the late 1950's, was designed based on hydrological data and information stretching back about 50 years. At present, the Kariba Dam has about 100 years of hydrological data and information. Whilst this is now a reasonably good data time-series to allow for reliable scientific analyses of trends and cycles, the effects of climate change are causing distortions and uncertainties to the predictions such analyses may give. This poses challenges in the management of the Kariba Dam and Lake Kariba for various stakeholder uses, as well as in the sound planning, decision and policy making processes pursuant to new infrastructure investments and developments for the effective and efficient utilisation and management of the waters and other resources of the Zambezi.

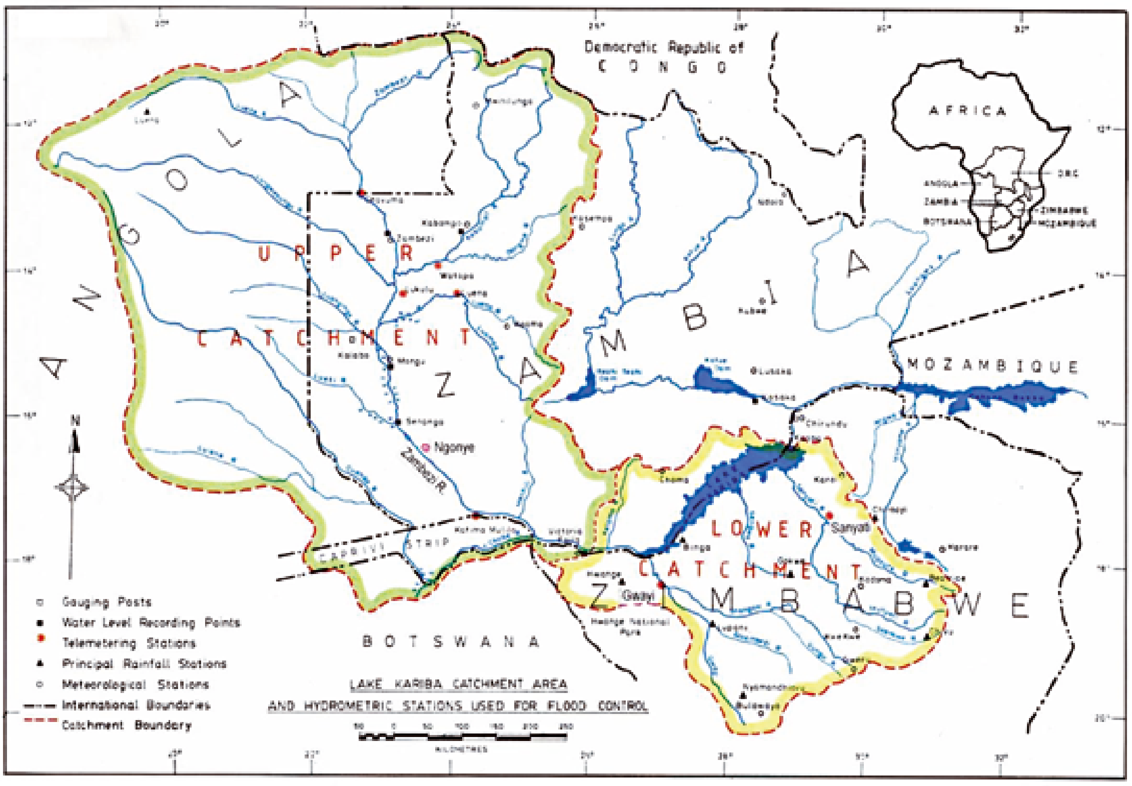


Figure 7.2: Lake Kariba Catchment Area

3. The Victoria Falls Flows

3.1 Recorded Years 1908 to 2007

Figure 7.4 shows the Dimensionless Differential Mass Curve for the recorded Victoria Falls mean annual flows for the period 1907/08 to 2006/07. This curve indicates the following cycles:

- Dry period 1907/08 to 1949/50 *(42 yrs)*
- Wet period 1950/51 to 1982/83 *(32 yrs)*
- Dry period 1983/84 to 1998/99 *(15 yrs)*
- Mixed wet/dry period 1999 to 2007 *(8 yrs)*

As can be seen from the above record, the cycles between wet and dry periods are becoming shorter and the last eight years do not shade much light on where the trend is going as this shows neither a wet nor dry bias. This could be linked to the uncertainties being brought to the fore by climate change and which make forecasts and predictions of future weather patterns much more difficult.

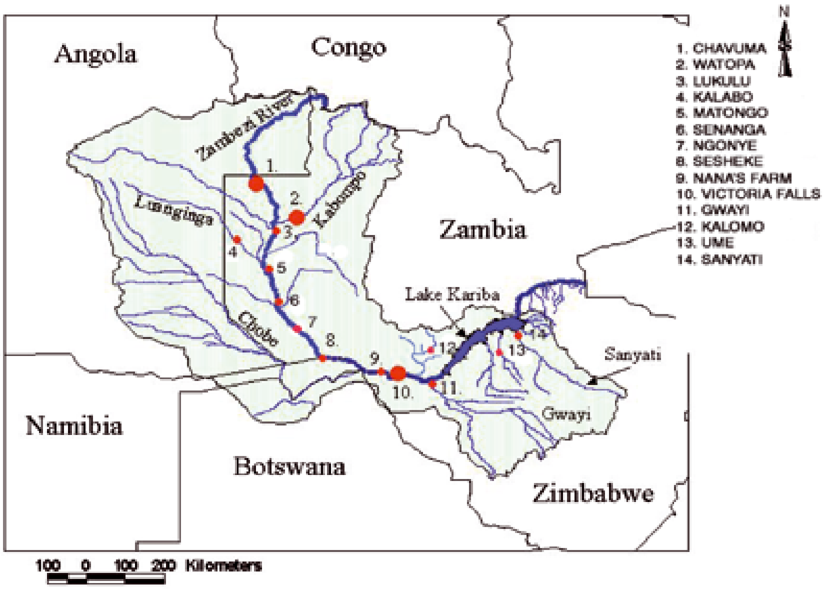


Figure 7.3: Lake Kariba catchment

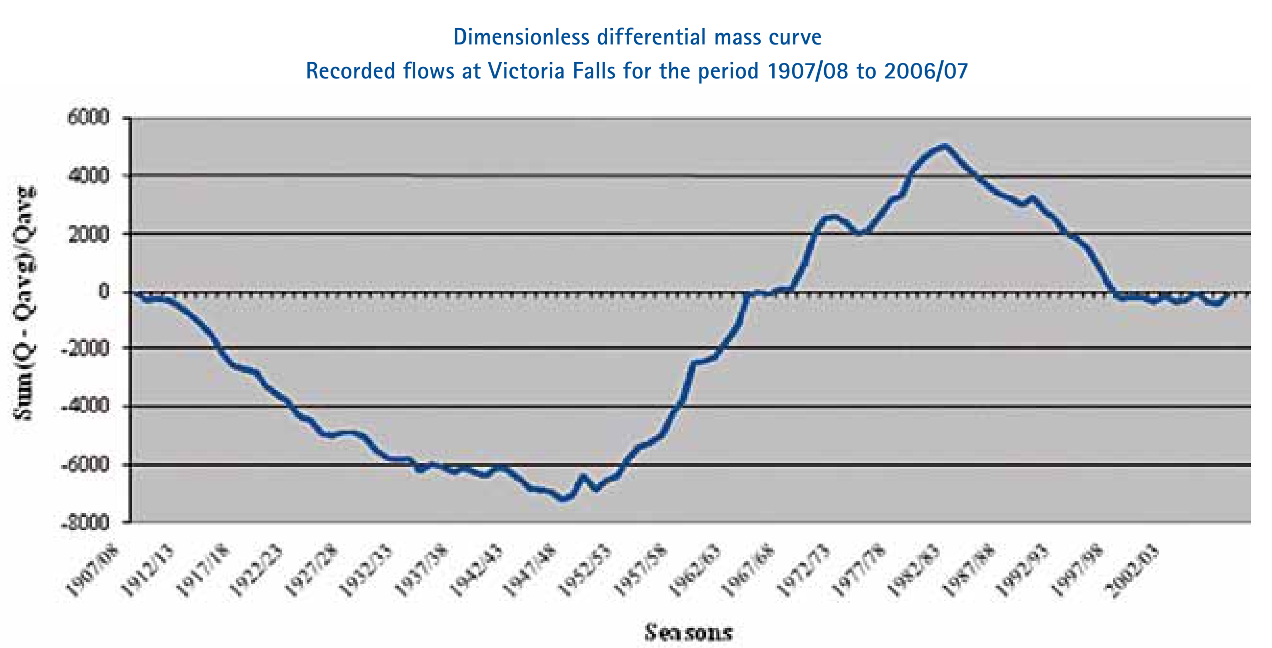


Figure 7.4: Dimensionless Differential Mass Curve for Victoria Falls, 1907/08 to 2006/07

3.2 Synthesised Years 2008 to 2038

Figure 7.5 shows the Dimensionless Differential Mass Curve for the recorded period 1907/08 to 2007/08 and the synthesized period to 2038/39. The synthesised data was obtained by using the Hydrologic Engineering Centre (HEC) Model 3 programme which utilises past recorded data to predict future flows. The longer the past recorded data series, the more accurate the HEC 3 predictions. This synthesis is done to enable us try and forecast future cycles/trends. The extended period indicates lower than mean flows at Victoria Falls, but at levels experienced at the turn of the 21st Century. This suggests similar inflow patterns into Lake Kariba for the next thirty years which would require additional storage capacity to both maintain hydropower outputs at installed capacity levels and to mitigate flood and drought events.

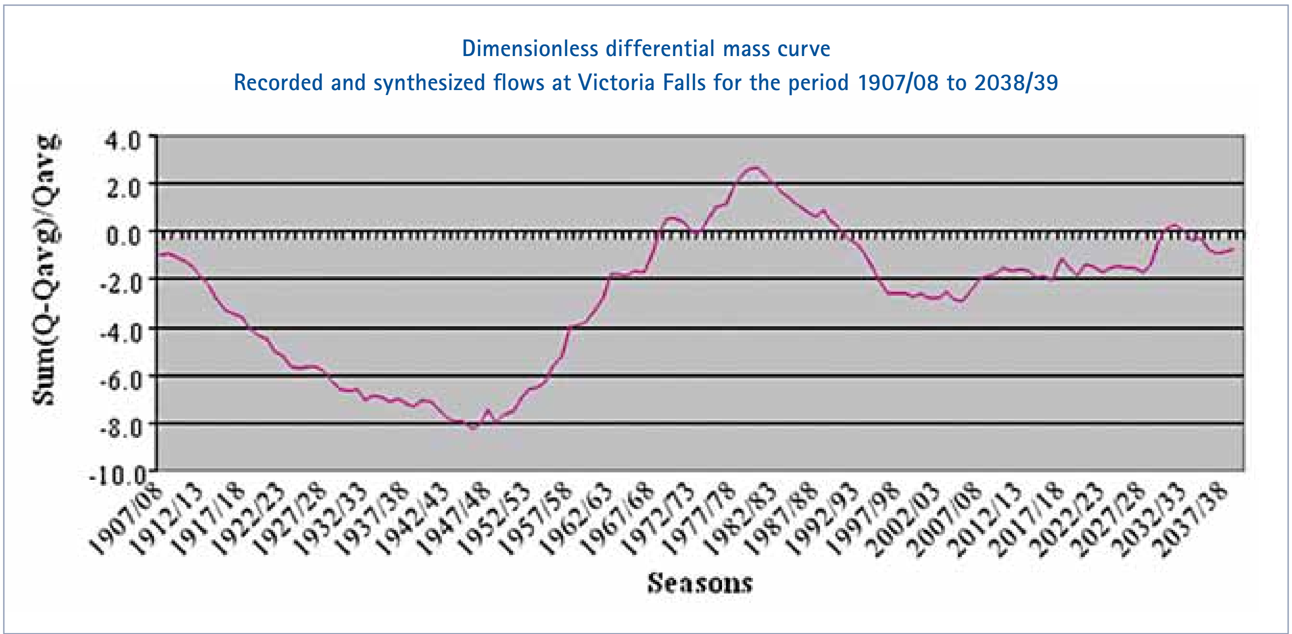


Figure 7.5: Dimensionless Differential Mass Curve for Victoria Falls, 2008 to 2038

4. Lake Kariba Water Levels

Lake Kariba started filling-up with the 1958/59 rainfall season and the lake levels have been recorded since. The original plan was to have the South Bank Power Station commissioned first, which was achieved in May 1960, whilst the North Bank Power Station should have come on stream by the mid-1960s. However, political developments did not allow this plan to come to pass. The then Federation of Rhodesia and Nyasaland was dissolved in 1963; Northern Rhodesia, now Zambia, attained its independence from Britain in October 1964.; the unilateral Declaration of Independence in 1965 saw Southern Rhodesia become Rhodesia and resulted in a liberation war for independence that finally gave birth to Zimbabwe in 1980. During the liberation war struggle for independence in Rhodesia, the borders between Zambia and Rhodesia were closed. As a consequence the Kariba North Bank Power Station was not operational until May 1976. Thus the Kariba Lake levels remained high with almost annual spillages of water prior to the commissioning of the North Bank Power Station. The 1970s also saw favourable inflows into Lake Kariba until the 1980s when inflows declined. This resulted in the lake levels dropping, a situation which was aggrivated by the Kafue Gorge Power Station fire which made it in-operational in 1989 thus placing higher reliance on Lake Kariba to produce the deficit. This is depicted in Figure 7.6.

The Kariba Lake levels follow closely what is depicted by the Dimensionless Differential Mass Curves in Figure 7.4. Positive gradients of the Dimensionless Differential Mass Curves correspond with gains in storage and lake levels whilst negative gradients correspond with drops in storage and lake levels.

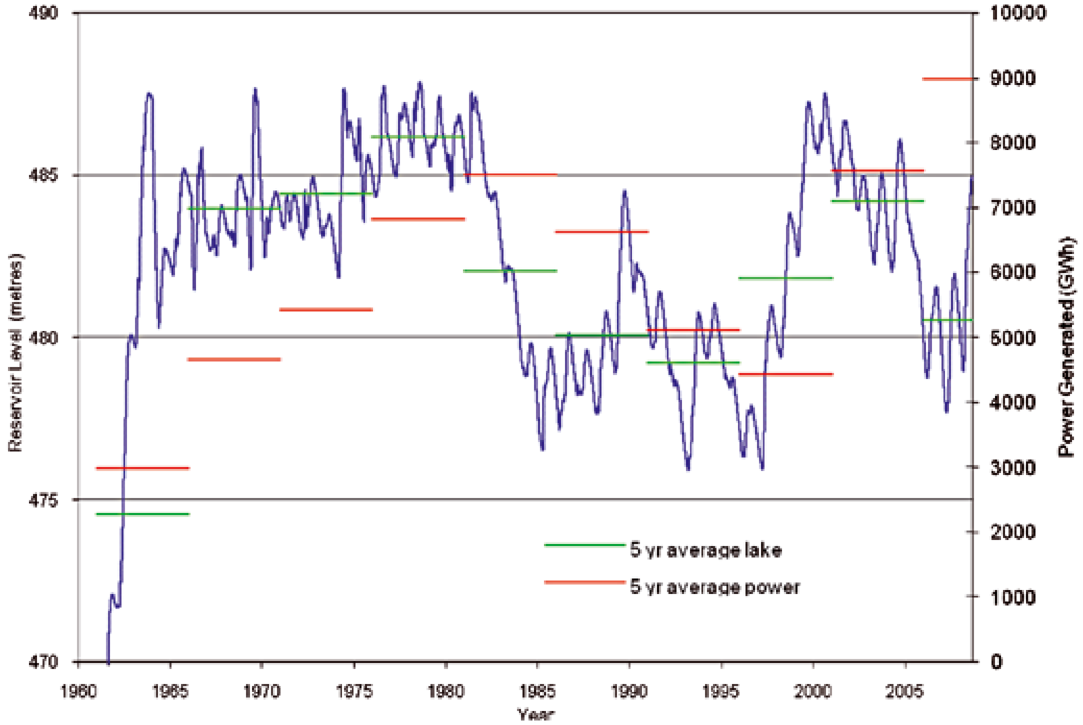


Figure 7.6: Five Year Average Lake and Power generation Levels at Lake Kariba

5. Hydropower Production

The production of hydropower at Kariba started modestly with the generation of power on the South Bank in May 1960. Generation from the North Bank commenced in May 1976 and brought the five year average production levels to 7 500 GWh per annum. The commissioning of the North Bank Power Station in the mid-1970s coincided with above average inflows into Lake Kariba. As Lake Kariba is a three year reservoir in respect of power generation, the five year average generation figures represent fairly the growth of hydropower generation until 1985. This was followed by a decline in hydropower production owing to reduced inflows experienced in the 1980s. This decrease in hydropower generation continued until the mid 1990s when production again started increasing, peaking to an annual average of 9, 000GWh in the 2000s. This is clearly depicted in Figure 7.6. This occured not only on account of improved inflows but also because of the rehabilitation and upgrading of the generation plant saw installed capacity increase from 666MW to 750MW on the Kariba South Bank and 600MW to 720MW on the Kariba North Bank. Further, the higher the water head (lake level), the more efficient the same cubic meter of water under pressure becomes in producing hydro-electricity. Thus, years of low lake levels utilise more water per GWh produced than in years of high lake levels. An additional element is that from 1998, ZRA started charging, on a monthly basis, the two power utilities, ZESA and ZESCO, for water used for hydropower production through a Water Purchase Agreement thus giving ZRA an incentive to allocate water for hydropower generation on a commercial basis and take higher risks in respect to predictions of future inflows into the Lake.

6. Kariba Temperatures

Figure 7.7 shows the Dimensionless Differential Mass Curve for the mean temperatures observed at Kariba Dam for the period 1965 to 2007. The curve clearly shows that for the period 1965 to 1983, the mean temperatures dropped, but that there has been a continued warming up of the mean temperatures since then. The dropping of temperatures coincided with an increase in water flows at Victoria Falls as indicated by the positive gradient of the Dimensionless Differential Mass Curve in Figure 7.5; whilst the increase in temperature after 1983 coincides with a decrease in water flows at Victoria Falls as indicated by a negative gradient of the Dimensionless differential Mass Curve in Figure 7.5. There, thus, appears to be a direct link between water flows observed at Victoria Falls with the mean temperatures measured at Kariba Dam: A general increase in flows at Victoria Falls being associated with lower mean temperatures recorded at Kariba Dam; or a decrease in flows with a general increase in temperatures.

The Dimensionless Differential Mass Curves for the Minimum and Maximum temperatures measured at Kariba as shown in Figure 7.8 presents the same picture as that given by the mean temperature curve. The predictions for the maximum and minimum temperatures upto the year 2038 are shown in Figures 7.9 and 7.10, respectively. The synthesised data for the extended period is obtained by using the Hydrologic Engineering Centre (HEC) Model 3 programme which utilises past recorded data to predict future temperatures. The longer the past recorded data series, the more accurate would be the HEC 3 predictions. In particular, the minimum temperature prediction shows a seemingly irreversible temperature increase to 2038. Table 7.1 presents a 5-year average lowest temperatures recorded at Kariba. This shows a cumulative increase in the 5-year average lowest recorded temperatures of +2.8°C over the forty year period 1965 to 2004.

The above observation ties in well with Magadza (1995) who reported that climate change models of the Zambezi River Basin indicate possible temperature increases of +40C to +50C.

Dimensionless differential mass curve
Recorded mass temperatures at Kariba for the period 1965 to 2007

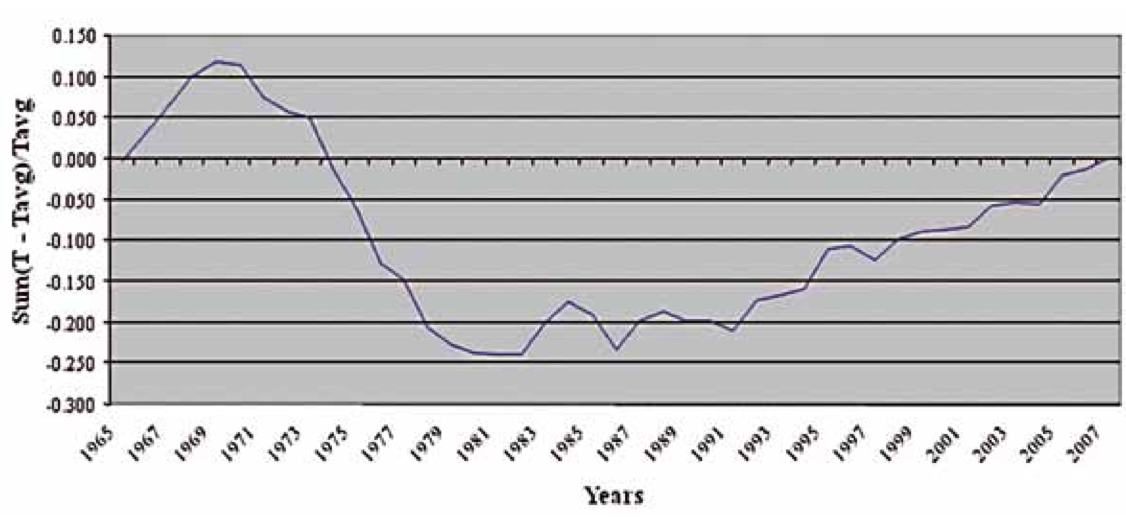


Figure 7.7: Recorded Mean Annual temperatures at Kariba Dam

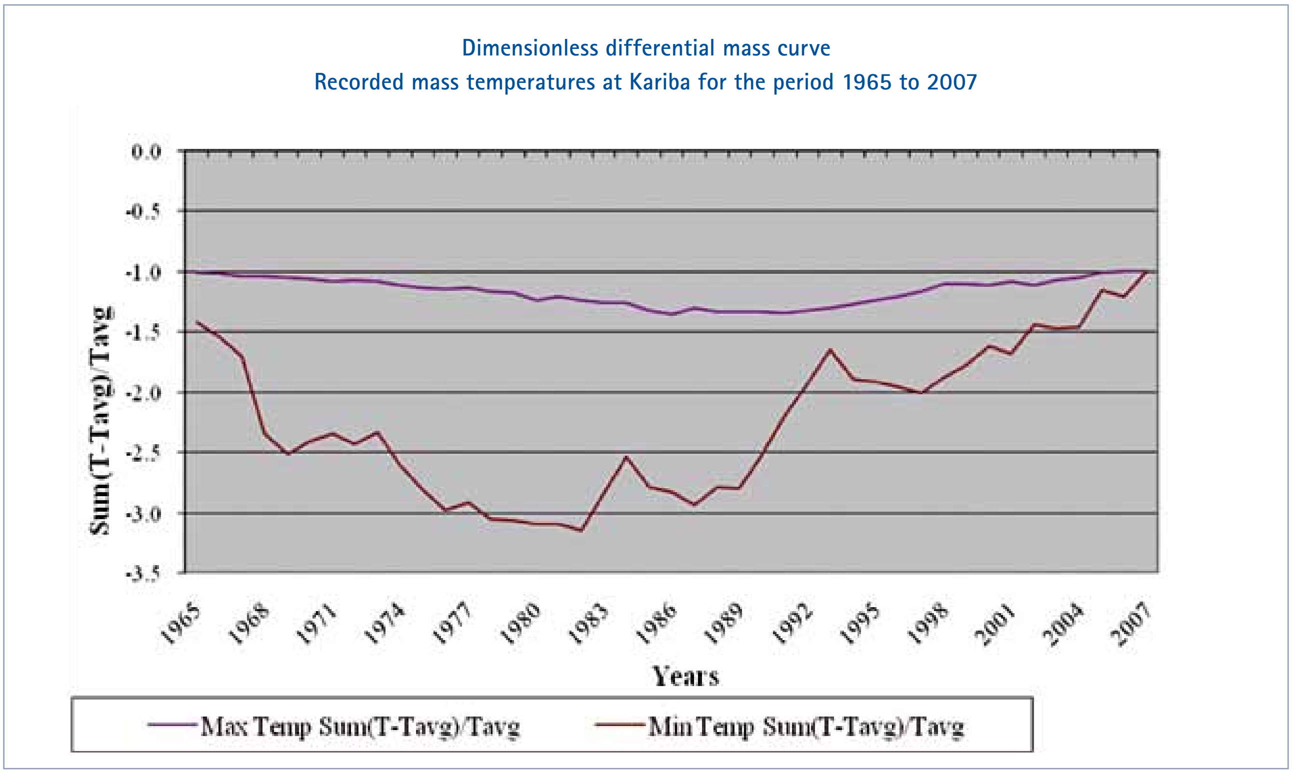


Figure 7.8: Dimensionless Mass Curve for Maximum and Minimum Temperatures at Lake Kariba: 1965 to 2007

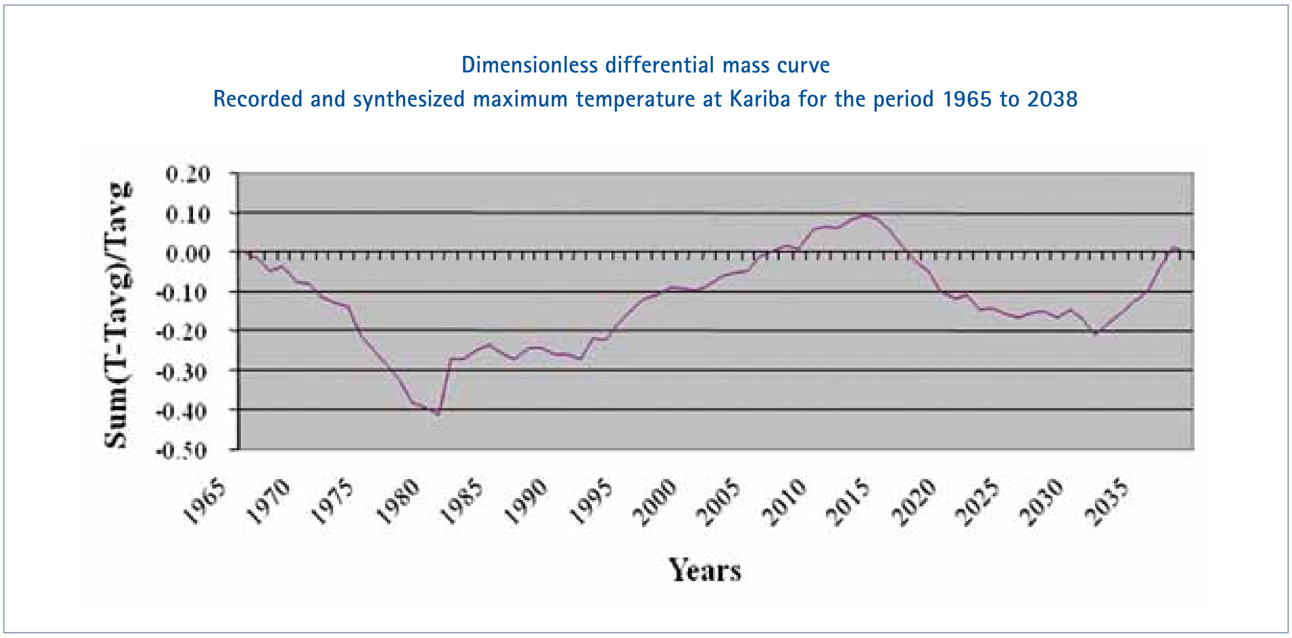


Figure 7.9: Dimensionless Mass Curve for Maximum Temperatures at Lake Kariba: 1965 to 2038

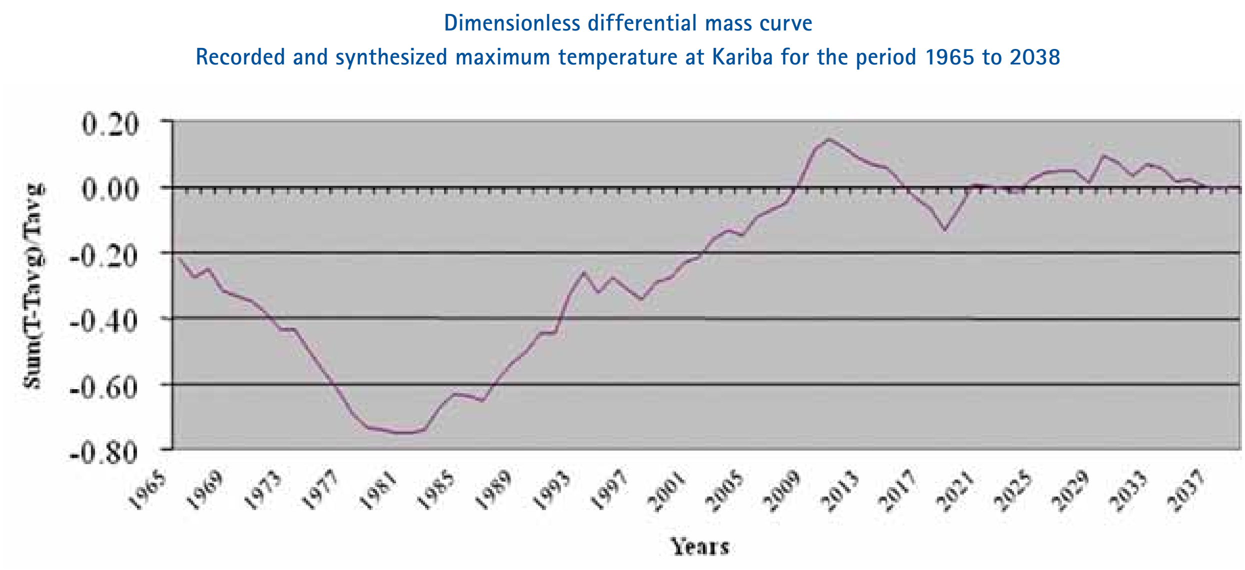


Figure 7.10: Dimensionless Mass Curve for Maximum Temperatures at Lake Kariba: 1965 to 2038

5 Year Period	Recorded Average Lowest Temperature (°C)	Cumulative Lowest Temperature Average Increase (Period to Period °C)
1965 - 1969	5.3	-
1970 - 1974	7.4	2.1
1975 -1979	6.9	1.6
1980 - 1984	8.4	3.1
1985 - 1989	7.2	1.9
1990 - 1994	9.0	3.7
1995 - 1999	7.8	2.5
2000 - 2004	8.1	2.8

Table 7.1: Five-Year Averages of the Lowest Recorded Temperatures at Kariba, 1965 to 2004

The effects on rainfall are not yet clear but the indications are for decreases of up to 10% in precipitation. Further, Euroconsult Mott MacDonald (2008) reports that the Zambezi Basin Models generally show a drying trend for much of the 21st Century, although the decade-to-decade rainfall fluctuations will continue.

7. Invasive Weeds on Lake Kariba

The two major invasive weeds on Lake Kariba are the water hyacinth (Eichornia Crassipes) and the Kariba weed (Salvinia Molesta). The proliferation of the invasive weeds on Lake Kariba poses operational problems for hydropower production; for example, if the weeds get into the intake works. Lake navigation and fisheries are also negatively affected. There is also higher evapo-transpiration due to the presence of the invasive weeds.

The Kariba weed was prevalent on Lake Kariba during its eutrophic phase, while filling-up in the early 1960s. A grasshopper from South America, Paulinia, was introduced in 1969 as part of a biological weed control strategy, in addition to a sardine species commonly known as Kapenta (Liomnothrissa miodon) from Lake Tanganyika. The grasshopper helped reduce the Kariba weed growth whilst the Kapenta helped reduce the Lake's nutrients. As the Lake's ecological balance was gradually achieved, the weed died out and is only now rarely observed on the Lake.

The water hyacinth on the other hand became a real nuisance from August 1994 when the Lake levels remained at lower levels than normal due to the prolonged below normal water inflows into Lake Kariba. In September 1996, estimated water hyacinth infestation on the Lake's Eastern Basin was Charara (400ha), Gatche Gatche Bay (850ha), Nyaodza (2 700ha) and Sanyati (40ha). Serious water hyacinth infestations were also observed in the Nyaodza area where water hyacinth leaf height averaged 1.25–1.40m while root length was between 0.90–1.24m. At all water hyacinth invaded areas, flowering was almost 100% from August to March and over 70% for the rest of the months. The leaves were healthy with no damage, except on very old leaves that showed slight disease symptoms. ZRA, together with its cooperating partners, undertook/effected a programme for reducing and controlling the proliferation of the water hyacinth through an extensive aerial spraying using the at the rate of 6 l/ha in August 1998. Water and fish samples were taken before, during and after the spraying exercise to determine any detrimental effects. None were detected and this spraying exercise is well documented (Zambezi River Authority, 1999). The spraying of the water hyacinth with 2,4-D was very effective and caused the death and submergence of the treated water hyacinth within one week. A total of 1 671ha were cleared of the water hyacinth. This was followed by the introduction of a biological control programme using weevils (Neochetina spp.) on the remaining water hyacinth infested areas which could not be sprayed, such as at domestic water intake works. This strategy is working well and the water hyacinth growth and proliferation is now well under control. ZRA has produced a "Management Tool Box" for the control of invasive weeds on Lake Kariba.

Water level fluctuations have an important influence on the infestations of water hyacinth and hence the management of the weed. Observations by ZRA staff show that a 5 to 10m change in the water levels of Lake Kariba is favourable to water hyacinth growth because shallower areas are formed are not subjected to as much wind and wave action. Once the dry areas become re-flooded , there will be mass germination of seeds and the weed will undergo rapid vegetative growth.

Further observations by ZRA staff confirm that water hyacinth plants become stranded and die as the water level recedes during the draw-down period in the dry season, leaving the area free for colonisation by germinating seedlings when the water level rises again. In the Gatche Gatche area on the Lake's Eastern Basin, water hyacinth was left stranded on dry land as the water level receded only to resuscitate when the water level started rising in November 2003. Figures 7.11 and 7.12 show water hyacinth stranded due to lake level recession.

Lake level variation definitely has an impact on the spread of water hyacinth but not in isolation. Other issues like nutrient loading and seasonal variations also play a role. However, it must be noted that data is not available to link the "disappearance or appearance" of weeds with the exact lake levels. However, Figure 7.13 clearly shows that the incidence or proliferation of water hyacinth principly related to the continued occurrence of low lake levels at Kariba. Table 7.2 provides a summary of weed spread estimates for the period 1992 to 2007 on Lake Kariba's shoreline. It is also postulated that an increase in temperature of around 2°C could increase growth rates of the water hyacinth, thus, increasing the management costs, particularly if herbicides are used to control the water hyacinth proliferation.

Year	Estimated extent of water hyacinth (Ha)	Comment
1992	684	April 1992 Landsat image classified in 1998
1994	1988	December 1994 Landsat image classified in 1998
1995	572	Charara, Gatche Gatche, Nyaodza and Sanyati East. September 1995 Spot Image
1996	3990	Charara, Gatche Gatche, Nyaodza and Sanyati
1997	4000	September, 1997
1998	4510	From the Dam wall to Chete Island
1998	3000	Pre-spray survey, September 1998
1999	300	February 1999
1999	350	Charara, Gatche Gatche, Nyaodza and Sanyati East. August 1999 Spot Image
2001	928	August 2001 Lake wide Boat Survey
2001	455	Charara, Gatche Gatche, Nyaodza and Sanyati East. Landsat Image for September 2001
2004	50	Charara, Gatche Gatche, Nyaodza and Sanyati. January 2004 Boat Survey
2004	Not Detected	Charara, Gatche Gatche, Nyaodza and Sanyati East. Landsat Image for November 2004
2005	Not Detected	Charara, Gatche Gatche, Nyaodza and Sanyati East. Landsat Images for March, June and November 2005
2005	10	Charara, Gatche Gatche, Nyaodza and Sanyati. December 2005 Boat survey
2007	20	July 2007 Lake wide Boat survey

Table 7.2: Summary of weed-spread estimates on Lake Kariba (1992 – 2007)

Figure 7.11: Water hyacinth left stranded in Gatche Gatche Bay after water level recession. (Picture taken on 02/12/2004)

Figure 7.12: Water hyacinth left stranded in Charara Bay after water level recession. (Picture taken on 02/12/2004)

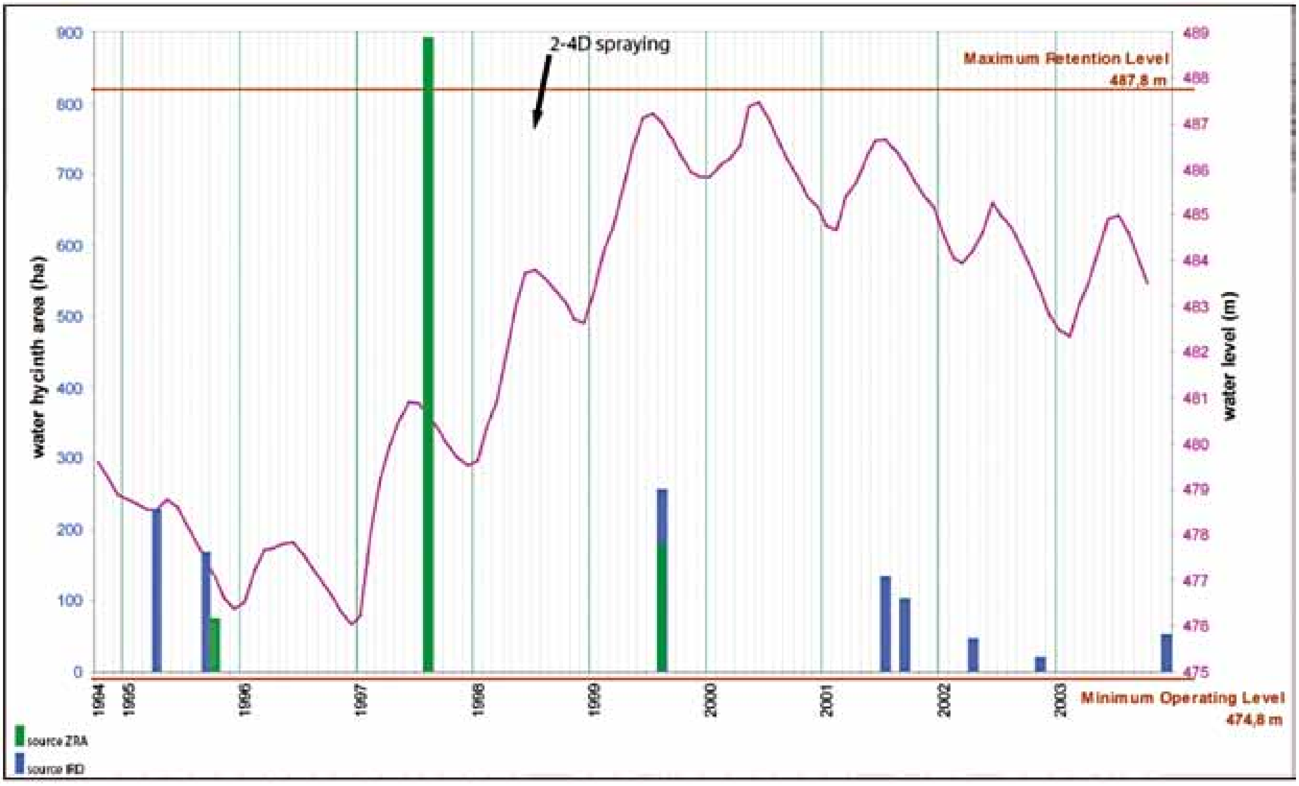


Figure 7.13: Water hyacinth occurrence in relation to Lake Level Variation at Lake Kariba

8. Adaptation Strategies and Mitigatory Measures

A link between the recorded temperatures at Kariba Dam with the flows recorded at Victoria Falls can be demonstrated. The recorded temperatures show an irreversible increase and collaborate with both global warming and studies by others. The Zambezi river basin Climate Change Models suggest a reduction in precipitation due to temperature increase, which in turn will result in lower inflows into Lake Kariba. The lower inflows into Lake Kariba will result in;

- Lower hydropower generation resulting in further power deficits in the region and lower revenues for the electricity utilities and ZRA
- Increased incidences of invasive weeds on the lake which adversely affect hydropower production, fisheries and lake navigation resulting in further economic losses in these sectors and increased costs in the management and control of the invasive weeds.
- The need for additional infrastructure investments in the form of water storage to cater for the increased variability in water flows due to climate change effects.

A doctor who diagnoses an illness correctly in the first instance will prescribe the correct medication, all things being equal. The correct diagnosis is made through thorough medical examination, the history of the patient and the full understanding of the human anatomy. The same can be said about formulating the right strategies and mitigatory measures to respond to the impacts of climate change. Our first line of defence is to understand the causes of climate change. For as the old proverb says "forewarned is forearmed". The potential uses of advance information are almost limitless. With good forecasting techniques, weather conditions can be anticipated and planned for in advance and to economic benefits.

Whilst some of the following adaptation/mitigation tools might be considered routine and necessary in a no-climate change scenario, their need becomes more pronounced and urgent in aclimate change scenario, with some of the tools requiring more resources than in a no-climate change scenario. Some of the adaptation/mitigation tools that can be used to assist adapt/mitigate the impacts of climate change and forecast flood/drought events for effective operations at Kariba Dam are;

- Supporting monitoring and research programs to measure and understand climate and the factors that affect it. This research should be refined to prioritise seasonal forecasts of rainfall. It is important to have seasonal rainfall forecasts which are as accurate as possible as such assists farmers, dam operators and other stakeholders plan for the oncoming season with better insight; thus, reducing operational risks.
- Increase the density and distribution of weather/climate monitoring equipment to increase accuracy of climate/weather predictions in the Zambezi River basin
- Development and use of statistical analyses that use past records to understand the favourable/precipitating conditions for various weather conditions.
- Use of statistical models that use past records to predict future conditions. One such model, using the "Dimensionless Differential Mass Curve technique", has been used to predict future wet/dry cycles/years for the Zambezi river system. Figure 3 for more details.
- Use of Global Climate Change Models in which software incorporates the fundamental laws of oceanic and atmospheric physics in a simulated world where weather changes over time. Specific information concerning the real world is then fed into the model to check how accurate the computer-generated results compare with actual observed data. Such Global Climate Change Models include the Goddard Institute for Space Studies (GISS), the Geophysical Fluid Dynamics Laboratory (GDFL) and the United Kingdom Meteorological Office (UKMO). It is however important to mention here that minimal downscaling of the global model predictions has been demonstrated for Africa, especially outside South Africa, and this is an important area for continued research.
- Capacity building, particularly in the Zambezi riparian states, to enable the regional and national institutions to collect accurate real time data, analyse and understand the results, make correct predictions and disseminate the information. Most politicians, who are part of the funding decision process and many others, do not understand the value and importance of accurate data. The need for them to be educated in this regard and so enable the regional and national meteorological/hydrological and research institutions aquire adequate funding to enable them to carry-out their functions competently, cannot be over emphasised. Good weather predictions/forecasts are invaluable to farmers, dam operators, flood/drought mitigation institutions and many other users of such forecasts. The data collection and analysis starts with these institutions.
- Because climate change is distorting current weather fore casting/prediction results and thus making dam operators

like the ZRA operate at higher uncertainty levels, Emergency Preparedness Plans or flood disposal/warming systems are important for both large dam operators and the flood/drought mitigation institutions. A region like the SADC should have a comprehensive flood/drought disaster and mitigation institution built up from national units. Large river basins like the Zambezi River should have comprehensive flood disposal plans such that dam operators do not operate their dams in isolation or independently. It is inconceivable what would happen if Kariba, Itezhi-Tezhi, Manyame, Mazvikadei and the Lake Malawi system would discharge their full spillway capacities simultaneously with a full retention level at Cahora Bassa to the Tete Province and Zambezi Delta regions of Mozambique.

- River catchment management is of paramount importance. Most reservoirs and rivers in the Zambezi River basin are silting up yearly due to poor catchment management. Runoff patterns are changing due to poor river catchment management. Population increase resulting in pressure on the available land and resources used for various purposes (grazing pasture, cultivation, firewood requirements etc), poor agricultural practices, the continued destruction of forests and increased human settlements all contribute to catchment degradation.
- Carbon dioxide (CO_2) concentrations are now increasing at compound rates of about 0.5% per year. The most common CFCs are increasing at approximately 5% per year. A doubling of pre-industrial CO_2 concentrations as early as 2030 is predicted if no remedial actions are taken, Bruce (1997). Carbon dioxide (CO_2) and CFCs emissions are the root cause of global warming. To curb this, there should be comprehensive international agreements to reduce atmospheric pollution which also support measures to slow down the rate of increase of greenhouse gases. In the Zambezi River basin, deforestation and reliance on fossil fuels should be discouraged and reduced.
- ZRA and its partners should encourage Zambezi River basin citizens to conserve water and use more efficient energy equipment and practices to reduce demand.
- ZRA and its partners should exploit the opportunities presented under various Climate Change Protocols as the Zambezi River basin is a huge carbon sink. A number of funding opportunities for financing various basin activities aimed at mitigating climate change effects should also be explored and utilised through carbon trading arrangements.
- Further investments are required in the case of the Zambezi River basin to increase storage and thus mitigate the expected lower precipitation levels in the basin. The additional new storage would be for hydropower generation, for example, the Batoka Gorge and Mpanda Uncua Hydroelectric Schemes, or for irrigated agriculture in the hinterland for improved food security or for flood and drought mitigation.

9. Implementation Challenges

There are a number of challenges that the Zambezi River riparian states, in which Lake Kariba is situated, and ZRA will face pursuant to implementing the strategies and adaptation/mitigatory measures above. The major implementation challenges are discussed below;

9.1 Poverty

Poverty is a relative word with several definitions. In the context of the Zambezi River Basin, poverty relates to lack of resources of production that enable or empower the populace to afford a decent standard of living. This lack of resources also includes access to information, health facilities, education and other services generally resulting in the affected population being diseased, illiterate and dependent. The main causes of poverty in the Zambezi River Basin are;

- poor economic government policies
- poor governance
- corruption
- inadequate access to land and capital
- poor prioritisation of use of available resources by governments
- natural disasters (droughts, floods).

Poverty is a threat and challenge to the sustainable integrated water resources management of the Zambezi River for a number of reasons, including;

- The persistence of poverty and deprivation is pervasive and results in high birth rates, prostitution and corruption. High birth rates increase demands on food production, employment, and health services etc which are already inadequate, and creates a vicious circle. Prostitution and HIV/AIDS are synonymous whilst politicians easily bribe the poor for their votes and abuse their human rights through their ignorance.
- On average 70% of the population of the Zambezi River Basin is rural and poor. The rural economy of the basin countries is principally subsistence agriculture. With limited agricultural inputs, equipment and land, poor agricultural practices are prevalent resulting in land degradation. This land degradation accelerates soil erosion leading to siltation and pollution of water sources.
- The poor have no access to alternative energy sources and rely entirely on firewood and charcoal. Large forests are being destroyed daily to meet this demand which not only produces greenhouse gases but also leads to deforestation and land degradation.

9.2 HIV/AIDS Pandemic

Southern Africa is one of the worst HIV/AIDS hit regions of the World. Over 60 million people have been infected with more than 25 million deaths since the first cases of HIV/AIDS were reported in the early 1980s. HIV/AIDS, which has been described by SADC (1999) as "one of the greatest social problems facing Africa", will continue to reduce the life expectancy levels of the Zambezi River Basin's population.

HIV/AIDS will continue to pose great challenges in implementing the strategies and mitigatory measures listed above for the following reasons;

- it has placed heavy demands on an already overstretched health sector service making a bad situation worse
- HIV/AIDS is killing the basin's most productive human resource aged between 18 and 45 years, thus, reducing the human capacity whilst wasting training and skills development resources
- HIV/AIDS poses a threat to development and economic growth. Recent studies show the negative impacts on both workers and employers resultant from HIV/AIDS (Brookings Institution, 2001)
- many families have been left without an income by the loss of one or both of the family's breadwinners, plunging those remaining into poverty

9.3 The Brain Drain

Like HIV/AIDS which is robbing Zambezi River Basin riparian states of its most productive citizens, the developed countries also continue to attract and retain what remains of this skilled manpower. This leaves the river basin with little or no capacity to either carry out research and development work nor to build adequate capacity to train new skills.

9.4 Financial Resources

There are inadequate financial resources in the Zambezi River Basin to adequately carry out research and development work, invest in adequate data collection and information dissemination service and in other infrastructure for hydropower, irrigation or road networks. These are basic pillars for development and growth which facilitate the practice of integrated water resources management (IWRM) leading to a better understanding by all of the impacts of climate change and the importance of mitigating these climate change impacts.

9.5 Institutional Management Structures

River Basin Institutions should be set up to manage river basins holistically and practice IWRM in these basins. It is however a major challenge to set up these multi-national river basin organisations as has been experienced in the Zambezi, Nile and other large river basins in Africa and world-wide.

9.6 ZRA Operations

Lake Kariba is operated in accordance to an Operation Rule Curve. This Operation Rule Curve (ORC) has been developed over the years taking into account the hydrology of the Lake Kariba catchment area. In the past it has been easy to follow and comply with the requirements and provisions of the ORC as predictions of the seasons' performances have been reasonably clear. With the uncertainties being brought about by the effects of climate change, future seasons' predictions are going to be difficult and additional forecasting tools will be required. This calls for a more flexible management regime of the operations of the Lake which should be more responsive to these hydro-meteorological uncertainties.

10. Conclusions

This Case Study highlights that the temperatures recorded at Kariba Dam show a seemingly irreversible increase linked to reduced flows at Victoria Falls resulting in lower inflows into Lake Kariba. The lowest recorded 5-year mean temperatures at Kariba are now on average higher by +2.8°C than those measured in the 1960s. Inflows into Lake Kariba have also reduced over the same period on average. This has adverse effects in respect to hydropower generation, lake navigation and fish production. The Case Study highlights how the threats and challenges that would arise could be addressed or mitigated by the ZRA and other stakeholders to ensure the sustainable and continued economic operation of Lake Kariba and Kariba Dam.

The management solutions so far applied should continue to be monitored and evaluated on an annual basis in respect to the invasive weeds. This is a continuous process for ZRA staff augmented by its partners and other stakeholders. However, issues of global warming and climate change are international and require commitment and action at international level and by everyone on planet earth.

References

Tumbare M.J. (Editor) (2000). Management of River Basin and Dams: The Zambezi River Basin, AA Balkema, Rotterdam/Brookfields.

Zambezi River Authority (1997). Kariba Dam's Operation Noah Relaunched, Mambo Press, Gweru.

Zambezi River Authority (1999). Report on the Control of Water Hyacinth (Eichornia Crassipes) on Lake Kariba, Lusaka, 28 November.

Magadza C.H.D. (1995). The Distribution, Ecology and Economic Importance of Lakes in southern Africa, Climate Change

Bruce J.P. (1997). Impact of Climate Change on Lakes and Reservoirs, Guidelines of Lake Management Volume 8: The World's Lakes in Crisis

Euroconsult Mott MacDonald (2008). Integrated Water Resources Management Strategy and Implementation Plan for the Zambezi River Basin, Lusaka, 30 April.

SADC (1999). SADC 1997/98 Annual Report, Gaborone.

Brookings Institution (2001). The Economic Impact of HIV/AIDS in Southern Africa, Barks – Ruggles et al, No 9, Washington.

Chapter 8

Climate Change and Variability

Impacts on Agriculture and Water Resource and Implications for Livelihoods in Selected Basins

By Amos E. Majule (PhD). Senior Research Fellow. Institute of Resource Assessment (IRA). University of Dar es Salaam. Dar es Salaam, Tanzania

Contents

1. Abstract

Climate change has now become an additional threat to natural resource and community livelihoods, putting pressure on already stressed hydrological systems and water resources. Agriculture is one of the major sources of livelihood for the majority of communities living in rural areas of the southern sub-Sahara region.

The type of agriculture practiced depends on rains and this has been significantly affected by climate change and variability. This paper presents facts about climate change and its impacts on community livelihoods, particularly on agriculture at basin level by drawing examples from different case studies in the Lake Nyasa, Rufiji River and Shire River basins. According to scientific data and views from the local communities, there is evidence that temperature has been increasing progressively since the 1970s with significant impacts on both crops and livestock whereby rainfall is now becoming more variable. Although communities have developed some coping and adaptation mechanisms, there is an opportunity for enhancing adaptation if proper approaches can be taken such as regional integration in managing shared water resources. This paper proposes a capacity building process applicable amongst different stakeholders within agricultural innovation systems at basin level. In this case, a combination of sustainable livelihood approach, innovation systems and learning alliance seems to suit most basins where different institutions and activities interact. To conclude, there is a need for a proper institution that will ensure that shared basins are properly managed in a sustainable manner to the benefit of all parties involved in order to strengthen adaptation.

Keywords: Agriculture innovations, vulnerability, livestock, capacity building, sustainable livelihood

2. Introduction

Climate change and variability is one of the primary environmental concerns of the 21st century (Orindi and Murray, 2005). It has direct and indirect effects on people's lives and development process. The effects depend on location, economic conditions, social systems and issues such as poverty as determined by income levels and food security, conflicts, technology, health, education level. In developing countries the effects of climate change and variability are especially severe because of weak adaptation capacity (Eriksen, 2001).

Declining water levels in the East African Rift Valley lakes, river flows and drying of wetlands have been linked with climatic change, particularly drought (AIACC,2006). This is threatening the livelihood of communities and national income as well as wetland ecosystems at large. In Tanzania, over the 20th century, the spatial extent of Kilimanjaro's ice cap has decreased by 80% due to global warming which has been affecting water availability downstream particularly with regard to the River Pangani (NAPA, 2007). Such effects increase land resources degradation and reduced agricultural, livestock production and hydropower generation (Yanda et al., 2006).

Rural households in developing countries tend to rely heavily on climate-sensitive resources, such as local water supplies and agricultural land (Orindi and Murray, 2005). Climate-sensitive activities include arable farming and livestock husbandry as well as natural resources such as fuel wood and wild herbs (Olmos, 2001; Pew, 2006). Climate change can reduce the availability of such local natural resources, limiting options for rural households that depend on natural resources for consumption and/or trade (IPCC, 2001a; Low 2005; Majule et al., 2007b; Yanda et al., 2006). Land may become less fertile, less local fuel wood for cooking may be available and water shortage may occur. Such problems increase demand on land resources, thereby increasing vulnerability to climatic events (Low, 2005).

Climate change and variability affect both natural and human systems. It affects water resources, land productivity and environmental biodiversity (Orindi and Murray, 2005).

To deal with climate change and variability problems, different coping and adaptation strategies have been suggested, but often such strategies have led to environmental resources depletion in rural areas if not well implemented. To enhance adaptation there is a need to initiate sustainable strategies on natural resources management (Whyte, 1995). Such strategies must provide an environment for local people to understand possible impacts of climate variability and how cope and adapt from such impacts. A collective effort from individuals, communities, civil organizations, Non-Governmental Organizations, government and international community is needed in order to address impacts associated with climate change and variability (Orindi and Murray, 2005).

3. Conceptual Framework: Climate and Associated Impacts

Figure 8.1 presents a conceptual framework that depicts several interacting factors associated with climate change and variability and their implications on environment, livelihoods and policy. In summary, climate change results in water resource degradation in terms of quality and amounts due to floods and drought. This may, however, also be due to poor management practices. Societies have to cope with such impacts using different strategies which may be sustainable or not (Orindi and Murray, 2005). Poor practices may lead to further degradation of water resources. In the planning process for strategies based on what is existing, one needs to have proper policies that will ensure sustainable adaptation. For countries sharing transboundary water resources, their interests need to be harmonized.

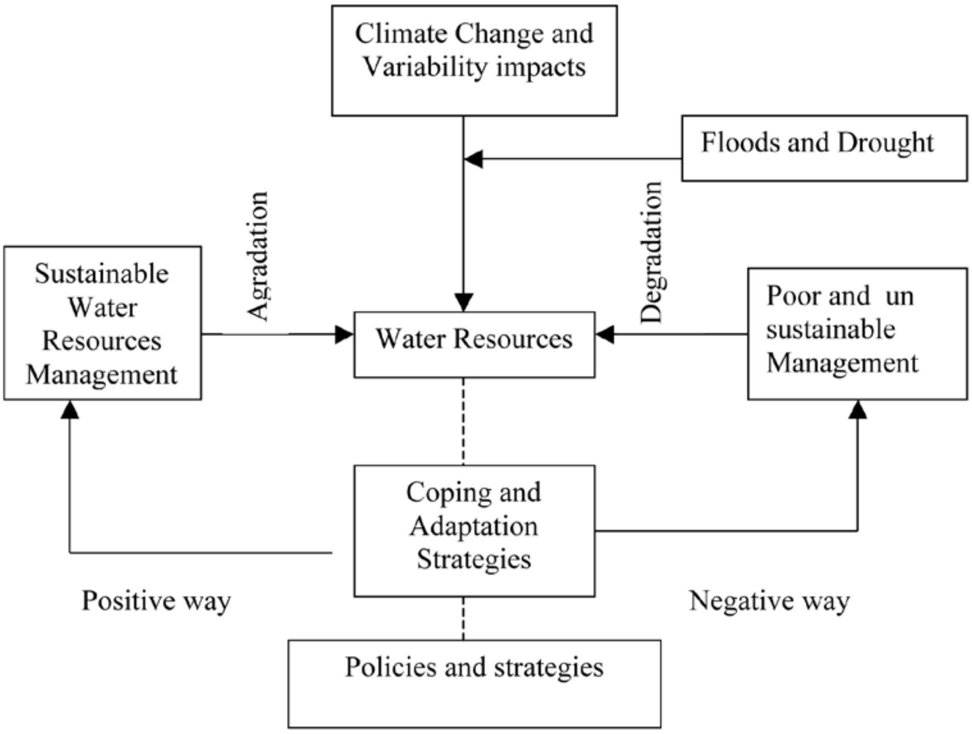


Figure 8.1: Conceptual Framework; Modified from Gwambene (2007)

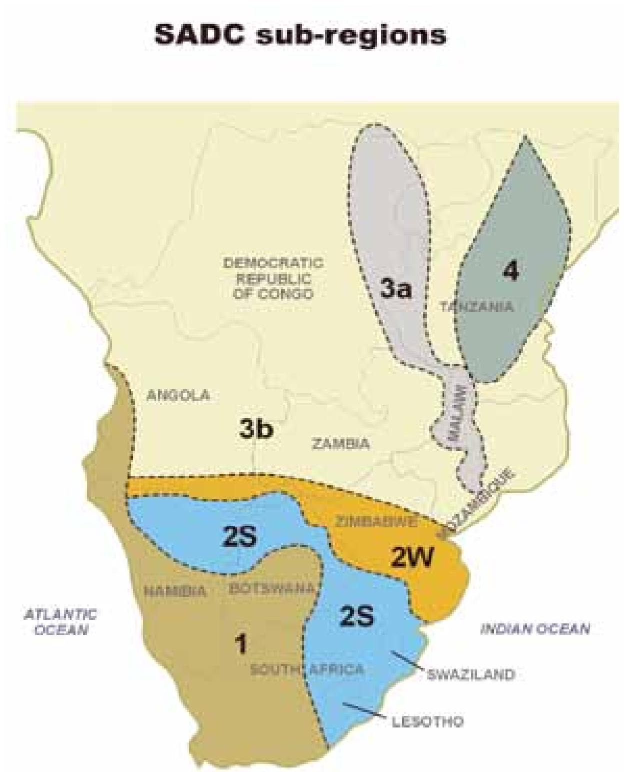
4. Definition and Application of Concepts

4.1 Climate Change and Variability

Climate is the long-term average weather of a region including typical weather patterns, frequency and intensity of storms; cold spells; and heat waves. Climate change refers to changes in the average climate in long-term trends, such as changes in average temperatures. According to the Intergovernmental Panel on Climate Change (IPCC), climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2001a). However, according to the United Nations Framework Convention on Climate Change, climate change refers to a change in climate that is attributable directly or indirectly to human activity that alters atmospheric composition (Olmos, 2001).

Climate variability refers to variation around the average climate, including seasonal variations in atmospheric and ocean circulation such as the El Niño-Southern oscillation. It is the shift from normal experienced rainfall pattern of seasons to abnormal rain pattern including temperature.

According to the IPCC (2001) the global average surface temperature increased over the 20th century by about 0.6°C. During this period of global temperature increase there has been a decrease in the extent of snow and ice cover, a rise in average sea level as well as the heat content of our oceans, and a number of changes in weather patterns that can also be associated directly or indirectly with the rising temperatures and reduce the intensity of rainfall (Majule et al., 2007a&b). In the SADC region (Figure 8.2) climate change scenarios haveindicated that the region is likely to be affected differently and thus creating pressure on agricultural systems and food crop production. This may require large investments in agriculture particularly damming for irrigation which is another burden to such countries.



Region 1:
< 400mm; Climate change (CC): Significant warming in this region; reduction in winter rainfall. Heavy ground water dependence

Region 2:
400-1000mm. CC: moderate temperature increases; winter drying; small decrease in rain=large decrease in run-off - impact on subsistence and dryland agriculture.

Region 3:
High rainfall area; CC: increase in extremes cyclones; sea level rise (in Mozambique); moderate temperature increase; Decrease in winter rainfall, increase summer (mod); malaria endemic;

Region 4:
lower, bi-modal rainfall; links with East Africa & Malawi; increase summer rainfall, moderate temperature increase.

S: stronger institutional base
W: weaker institutional base
a: population pressure
b: weak economies and poor infrastructure

Figure 8.2: Predicted Climate Change Scenarios in SADC Countries. Source: GWP-SA (2008).

Based on studies conducted in different river basins in Tanzania and Malawi, climate change and variability has been identified as occuring as indicated by increasing temperatures and rainfall variability (see Figure 8.3, 8.4, 8.5 and 8.6).

It has been shown (Figure 8.3 and 8.4) that generally speaking there has been an increase in maximum temperature at all stations. Secondly, it is apparent that the maximum temperature in Dodoma (Figure 8.3) on average steaded from 1966-1998, from when the maximum temperature started to increase continuously, suggesting warming in recent years. With regard to the Mbeya station in the Rufiji basin in Tanzania (Figure 8.4), the maximum temperature oscillated from lows in the 1961 increased up to 1970 and fell slightly to 1982 and thereafter increased continuously to date, again indicating warming. As compared to the data from the Dodoma station (Figure 8.3), there are more increases in temperature, indicating the area is highly sensitive to the effects of global warming.

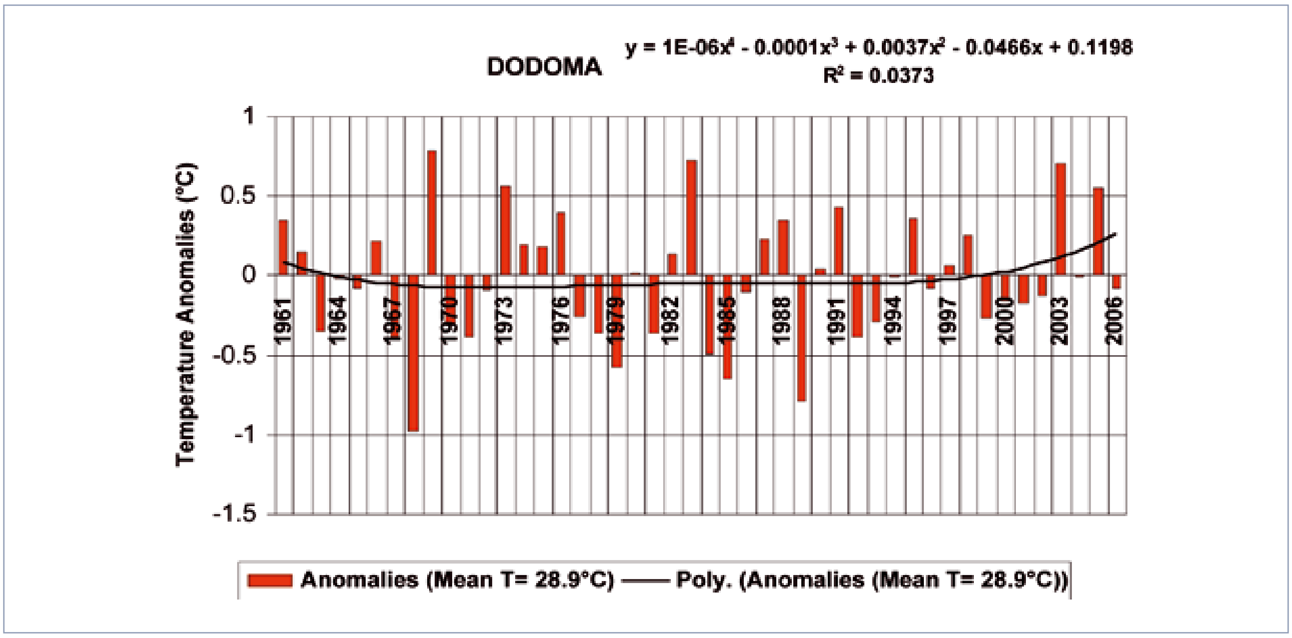


Figure 8.3: Anomalies of maximum temperature in Dodoma (internal) 1961-2006

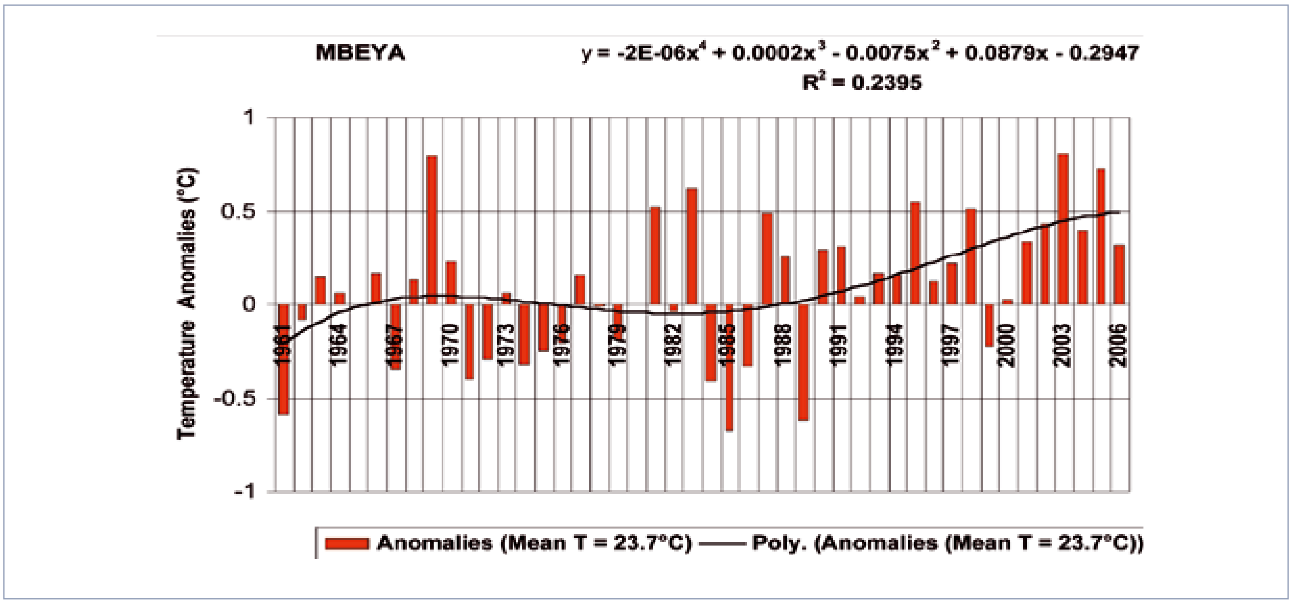


Figure 8.4: Anomalies of maximum temperature in Mbeya (Rufiji Basin) 1961-2006

Minimum Temperature

The Minimum temperatures in Dodoma (Figure 8.5) were initially below the mean value of 16.8 Degrees Celsius but continued to increase surpassing the mean value around 1986 and have continued to increase to date. The period with the highest rate of temperature increase is 1995 onwards. Minimum temperatures in Mbeya (Figure 8.6) steadily decreased below the mean and turned around in 1971 and have continued to increase to date. The period which showed the highest temperature increase was from 1998 on wards.

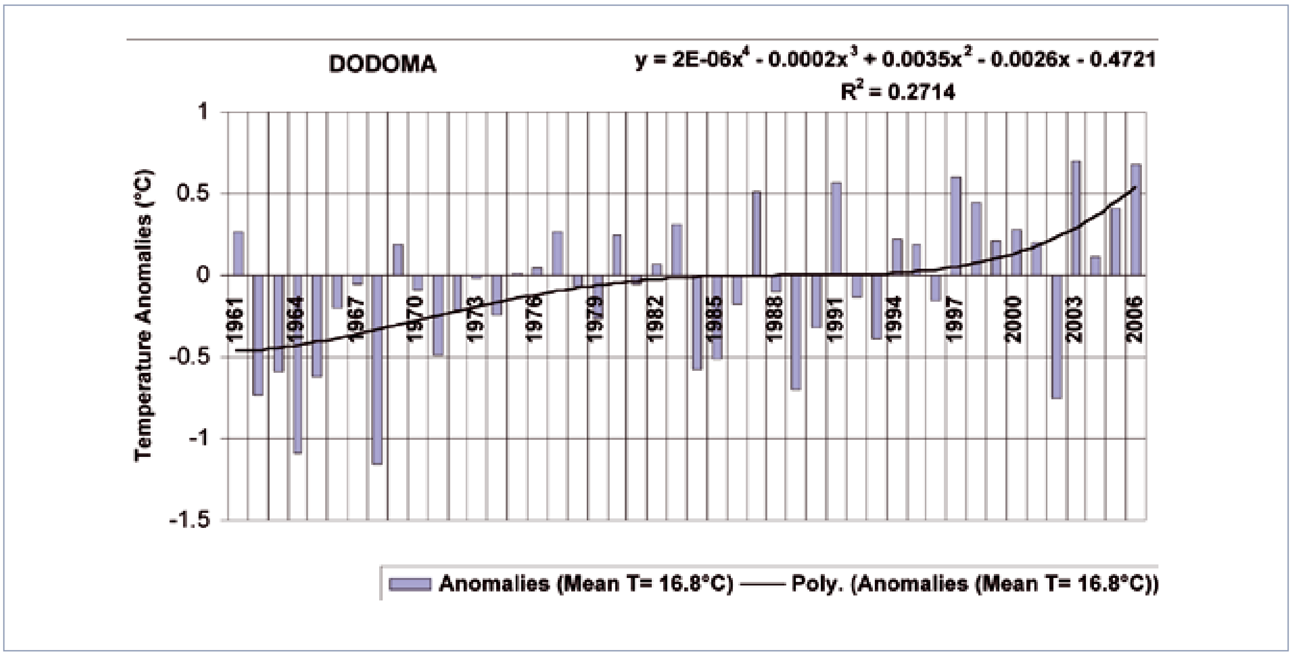


Figure 8.5: Anomalies of minimum temperature in Dodoma 1961-2006

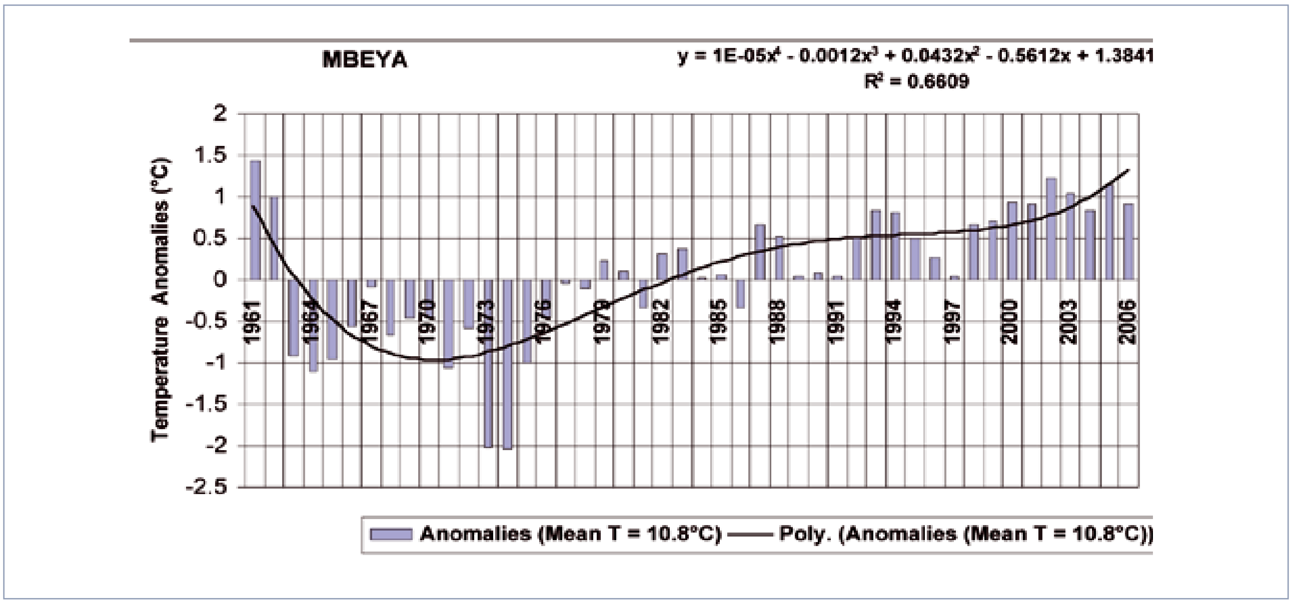


Figure 8.6: Anomalies of minimum temperature in Mbeya 1961-2006

4.2 Vulnerability

Vulnerability is defined as the likelihood that an individual or a group of individuals will be exposed to and adversely affected by dreadful conditions. It can also be defined as characteristics of individuals or groups in terms of their capacity to anticipate, cope with, resist and recover from impacts of environmental change (Galvin et al., 2001, Olmos, 2001; Majule et al., 2007a&b). Vulnerability can be described as the function of three overlapping elements: exposure, sensitivity, and adaptive capacity. For example, agricultural vulnerability to climate change is described in terms of not only exposure to climatic conditions but also crop yield sensitivity and farmers ability to adapt to the effects of that sensitivity.

The severity of impacts experienced will depend on the resources available to a given group or an individual. For example communities living in basins located in high potential areas are likely to suffer less as compared to basin in low potential areas (Majule and Mwalyosi, 2005; Yanda et al., 2006; Majule et al., 2007a).

4.3 Adaptation and coping strategies

Adaptation is defined as adjustments in social or economic systems made in response to actual or expected climate effects (Olmos, 2001; Galvin et al., 2005). These adjustments are intended to reduce the society's vulnerability to changes and variability in the climate system (Kates, 2000; Galvin et al., 2005). Feenstra et al. (1998) refer to all responses to climate change that may be used to reduce vulnerability as adaptation. Adaptation considers such factors as the ability of a system to cope with or absorb stress or impacts and to "bounce back" or recover (Orindi and Murray, 2005). Adaptation can also refer to actions designed to take advantage of new opportunities that may arise as a result of climate change. Adaptation can be spontaneous or planned, and can be carried out in response to or in anticipation to changes in conditions (Olmos, 2001).

In a development context, a prudent adaptive response to threat of climate change and variability may be to improve adaptation to existing climate as well as its variability, including extreme events (Feenstra et al., 1998; IPCC, 2001a). Improving adaptation to current climate variability is not only preparing an alternative for adaptation to longer-term changes in climate, but is also a useful and preparatory step that strengthens capacity now to deal with future situations without degrading land resources (Pew, 2006).

There are numerous general and specific adaptation measures depending on spatial-temporal parameters and the affected sector within the River Basin. Adaptation measures as outlined by Olmos (2001); Orindi and Murray (2005); and Low (2005)

Figure 8.7: Vulnerability: the likelihood that an individual or a group of individuals will be exposed to and adversely affected by dreadful conditions (Cutter, 2001).

include: Increase in sustainable irrigation to boost crop production; introduction of low water use crops and adoption of sustainable water resource management techniques following IWRM principals (seasonal rainfall harvest and water quality control). In addition an increase capital investment in reservoirs and infrastructure; reducing water loss through water conserving technologies and making water resource management an attractive career and field of investment (ibid).

4.4 Sustainable livelihoods

The sustainable livelihoods framework presents the main factors that affect people's livelihoods, and the typical inter-relationships (www.livelihoods.org). A sustainable livelihoods approach puts people at the centre of both our conceptualization and planning and the assessment of the impact of implementation. Vulnerability is explicitly considered within the framework in terms of trends, shocks and seasonality affecting livelihood options. The approach provides a means of understanding people's current capacity (assets or capital endowments) and how these are currently or potentially converted into livelihood outcomes, particularly adapting to climate change and variability. The importance of different types of assets (human, social, natural, financial and physical) and the relationship between them provide insights into environmental, social and economic factors influencing people's capacity to adapt. Structures and processes are keys to mediating people's actual livelihood strategies. These include public and private sector organizations and formal and informal institutions. This component of the framework provides an obvious link with an Innovation Systems Approach (ISA).

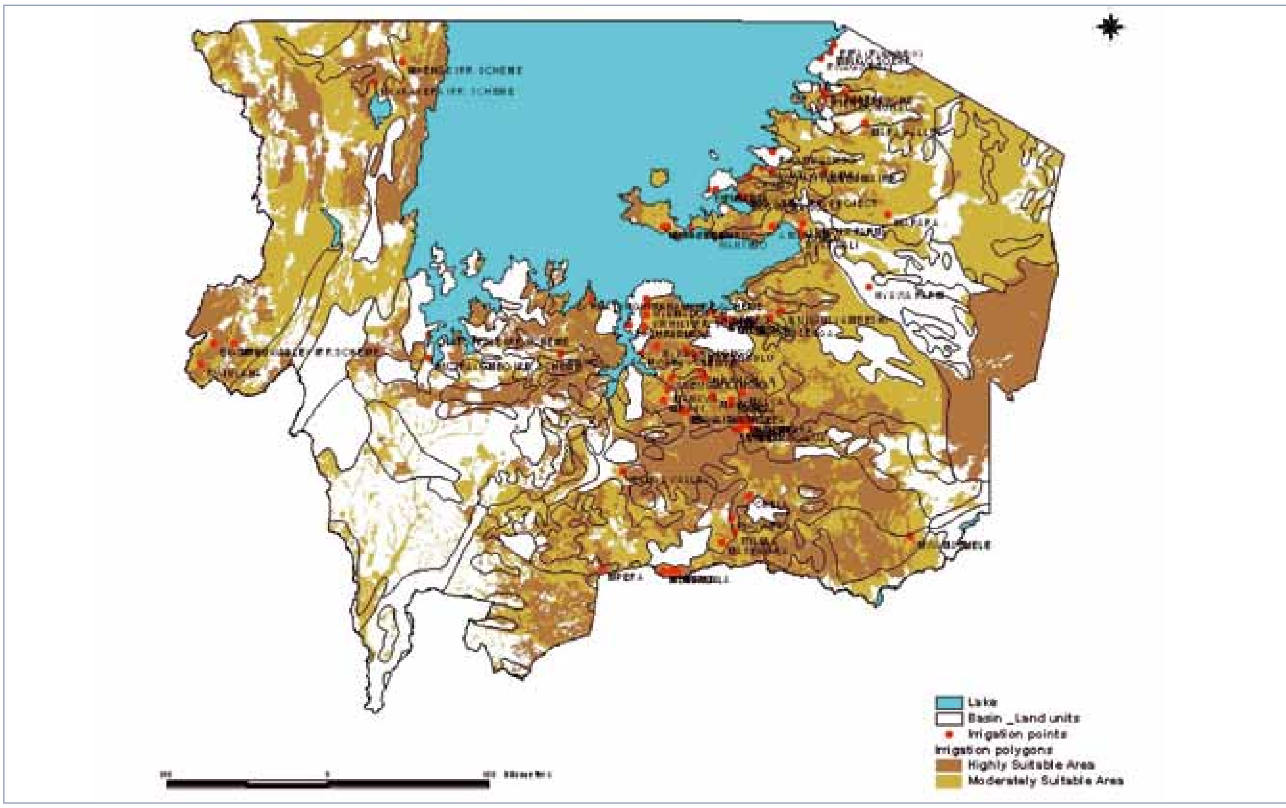


Figure 8.8: Potential irrigation areas mapped in the Nile Basin area of Tanzania

5. Challenges and Opportunities arising from Climate Change and Variability in Basins

Most lake and river basins in sub-Sahara Africa are sources of livelihoods, in particular through agriculture. They are important because they support agricultural production (both crops and livestock) in a number of ways (Majule and Mwalyosi, 2005). Agriculture production is enhanced because; i) improved soil fertility particular through the presence of fluvisols and vertisols which are very rich in soil nutrients due to flooding and natural fertility; ii) most of the basins are endowed with different water sources, such as a river which can be a very good source of water for surface irrigation and so different crops and vegetables can be cultivated throughout a year; iii) Livestock production is very high due to the pasture and water availability and iv) they are potential source of income to the communities through fishing and harvesting of macrophytes for different purposes. Because of such factors river basins are densely populated due to immigration: Populations having realized that they are potential areas for adapting to threats arising from climate change and variability.

5.1 Impacts of climate change on water resources

It has generally be established that the warming of sea surface temperatures may lead to increased droughts in equatorial and subtropical Eastern Africa ,and less precipitation during already dry months can lead to drought and increased desertification (IPCC, 2001). According to URT (2003), annual flow reductions of 6–9% in the River Pangani and 10% in the River Ruvu have been reported and observed to have had significant implications on food crop production and livestock in general (Majule and Mwalyosi, 2005). Changes observed include, for example, drying of flood plain and encroachments of wetlands. Other studies conducted in selected rivers in the Ruaha sub-catchment in Tanzania have also indicated a reduction in annual daily river flows (Majule and Mwalyosi, 2005). Such changes could be also linked to catchment degradation associated with poor farming practices such as cultivation on river banks and sometimes within river beds during the dry season. Poor land management practices up-stream such as deforestation and overgrazing of land are among the factors contributing to river sedmentation and hence reduction in water flows.

In response to such changes, improper agricultural practices have been practiced such as cultivation of crops near river banks, or sometimes even within river systems. This causes further reductions of river flows through siltation due to soil erosion.

The disappearance of Mount Kilimanjaro's glaciers is anticipated by 2015–2020, and will have significant implications for natural resources and communities downstream. For example, the Pangani River Basin is fed by the glaciers of Kilimanjaro; the population living around the base of Kilimanjaro uses this melt water and the fog water from the rainforests that cover the mountain's flanks for drinking, irrigation and hydropower. In the southern highland areas of Tanzania, the recently recorded decreasing Crater Lake levels are closely linked to warming and this is associated with loss of springs around lakes which are very important for agricultural activities around the Lakes (Garcin et al., 2006). Drying of land and reduction of rainfall is responsible for the frequently reported droughts and hunger in the region (Majule et al., 2007a&b).

In the agricultural sector, there is a need to reduce water losses in the irrigation system by making water supply more efficient (Pew, 2006). Construction of water reservoirs and water transfers across basins form part of the government's adaptation activities (Orindi and Murray, 2005). Improvement of access to alternative water sources during drought is a particularly important coping strategy (ibid).

Ensuring rights to water access by the poor (for example, small-scale irrigators), in line with the Millennium Development Goals, is an important mechanism to minimize water loss and conflict resolution (Orindi and Murray, 2005). Recognition of the traditional water rights of small-scale irrigators in formal laws is one adaptation mechanisms (URT, 2003). However, current reorganization of the water sector aimed at formalizing such rights is already marginalizing the poor especially those who cannot afford to pay the, inevitably, associated fee (Maganga et al., 2003; Van Koppen et al., 2004 cited in Orindi and Murray, 2005). Although formalization of water rights is supposed to bring efficiency and improve water management, it has ended up creating a large number of 'illegal' users such that authorities can do nothing about it (Maganga et al., 2003 cited in Orindi and Murray, 2005).

5.2 Impacts of Climate Change and Variability on Community Livelihoods

5.2.1 Impacts on crop production

The livelihoods of the majority of people living in rural areas of Tanzania depend on agriculture and other natural resources, particularly forest products (Majule et al., 2008). In many sub-Saharan African (SSA) countries, smallholder agriculture underpins most rural livelihoods and national economies, and worsening poverty and increasing food insecurity is closely linked to low and/or declining levels of agricultural productivity. In the medium term, appropriate means of enhancing agricultural growth and productivity are key components of a viable and widely applicable poverty reduction strategy (Thirtle et al., 2001). An appreciation of this has renewed interest by African governments (e.g. NEPAD, 2003) and development agencies in increasing agricultural productivity. Already vulnerable to highly variable climatic and soil conditions, accelerating climate change and declining soil fertility poses further significant challenges to improving agricultural productivity in SSA (Devereux and Edwards, 2004). Table 8.1 presents a summary of the impacts of climate change and variability on three major crops grown in the Lake Nyasa Basin. Based on the perceptions of farmers' in the basin, the three major crops are affected differently by rainfall variations, increases in temperature and to some extent changes on wind patterns. Major changes associated with rainfall variation include unpredictable planting dates of different crops including maize and a shortening of the growing season. To adapt to such changes, farmers are using more resistant and early maturing maize varieties (Table 1) to increase crop yield. Rice production is reported to decline due to water shortage but farmers are practising water harvesting techniques to offset the negative effects. Commercial crops in particular cocoa, (Table 8.1), is also negatively affected by both droughts and floods through impaired flowering and drying of the cocoa bean. Temperature increases (Table 8.1) also indicated negative impacts on major maize and rice crops through reduced yields associated with drying of soils. To cope with such impacts, there is increased cultivation in wetlands to secure crop yields in the basin.

In Tanzania agriculture is subsistence level in nature, and to a large extent depends on rainfall as well as natural soil fertility, both of which have been reported to be declining over years (Majule et al., 1997b). Likewise, in many countries in sub-Sahara Africa agricultural development through research has been advocated over years but results have rarely been effectively utilised by farmers. One of the major reasons for ineffective utilization of research findings has been reported to be ineffective planning of research programmes or projects in an innovative way that could enable the primary beneficiaries to benefit or use research findings.

Plant diseases also have a relationship to climatic factors such as humidity. An increase of humidity creates conducive environment for fungus generation with significant reduction in crop production. A good example is cashewnut production in the Ruvuma basin which is significantly affected by a fun-

Climate factors		Effects of climate change on three major crops		
Element	**Changes**	**Maize**	**Paddy**	**Cocoa**
Rainfall	Pattern	• Planting time is not predictable • Use of improved varieties • Increased harvest • More consumption of maize due to reduced amount of rice produced • Reduced harvest when floods wash away the crop • Replanting when onset of rain is earlier than expected and an extended dry spell sets in after planting – causing wilt	• Planting – can either be early or late • Planting of seeds instead of broad-casting • Shift to more resistant varieties • Increased use of pesticides • Reduced harvest or increased yield according to rainfall amount • Use of herbicides instead of wee-ding by hoe • Store at home instead of farm piles • Harvesting time change according to weather. It can be laborious to harvest during heavy rains • Difficult to store during heavy and prolonged rains	• Impairs flowering thus reduce yield • Heavy rains make the task of drying difficult • Reduced harvest when shortage of rain
Temp	Increase	• Reduced yield • Reduced soil moisture • Easy to dry the crops • Invasion of wetland cultivation • Increased tradition irrigation in valley bottoms • Increased production of vege-tables	• Reduce the task of weeding • Easy in prolonged sunny climate • Easy storage in hot weather • More disease incidence • Increased pest attack	• Easy to dry beans • Decrease produc-tion • Impairs flowering thus reduce harvest
Wind	Increased	• Fall of pure stand crops	• Reduce harvest	

Table 8.1: The Effects of Changing Climate on Three Major Crops in Lake Nyasa Basin, Tanzania. Source: Majule et al. (2007a&b)

gal disease known as powdery mildew, the incidence of which has been incresaing on account of global warming (Martin et al., 2005). The disease can reduce cashew yields to zero if not controlled. The control measures have both economic and environmental implications, particularly added production cost and soil pollution where sulphur is used to control the disease (Majule et al., 1997a).

In areas where rainfall will increase, the leaching of nutrients, removal of topsoil through erosion and impaired nutrients transformation under water logging conditions will affect plant development and eventually crop yields. It is predicted that due to anticipated changes, coffee for example will most likely be grown successfully where rainfall should increase, cotton growing areas, however, would be reduced. According to the Initial National Communications (URT, 2003), maize yield will be reduced by about 33 percent over the entire country.

5.2.2. Impacts on livestock production

Livestock production is also a major source of livelihood to the communities in river basins. The Climate Variability Assessment Report shows that at village levelfoot and mouth disease is still the most prevelant disese, with 60% followed by Ndigana 59% Rabies 49% and Anthrax 31%. At district level Ndigana is 90% foot and mouth is 88% Newcastle Disease is 87% Rabies is 85% and lastly Anthrax is 46%. The same reasons are give for their occurrence; climatic change, prolonged heavy rains or dryness. The Initial National Communication Report (URT, 2003) concludes by stating that climatic changes are bound to favour the occurrence of diseases and insect pests due to increased temperature and rainfall.

A situation analysis conducted in agriculturally less favoured and high potential areas of Tanzania and Malawi has indicated that pasture and water availability are becoming increasingly scarce in many areas due to changes in rainfall patterns and decreasing rainfall amount (Majule et al., 2007a&b). Alternatively, there is evidence that during high rainfall periods, Ndigana becomes a serious problem and rift valley disease is most prevalent following El Nino in central parts of Tanzania (Majule et al., 2007b). This component of the study aims at documenting the already observable and possible impacts of climate change/variability on livestock production.

5.2.3 Adaptation to Climate Change and Variability on Agriculture

Adaptation in agriculture involves improvement of crop and livestock management, since climate change leads to changes in cropping systems through shifting of agricultural zones and increased incidence of pests and diseases (Orindi and Murray, 2005). In adapting to climate change, farmers grow drought resistant and fast maturing crop varieties that grow well in areas of reduced rainfall (Low, 2005). This requires identification of the most suitable drought resistant crops in consultation with local communities so as to ensure acceptability among the farmers (NAPA, 2007). In most cases, farmers are reluctant to use certain drought resistant species because of their low market and consumption values in addition to the high labor investment associated with their cultivation (Olmos, 2001; Orindi and Murray, 2005).

Other agricultural strategies include management of tillage practices, for example, minimum or no tillage in hazard areas, planting cover crops and applying green manure to help restore soil fertility where leaching occurs from increased rainfall (Orindi and Murray, 2005). Many farming communities grow more than one crop as a form of insurance against total crop failure. Making better use of climate and weather data as well as forecasts and adjusting crop rotation practices to fit the new conditions could help to ensure sustainability of production systems (Orindi and Murray, 2005). Further, initiation of food and other social security programmes to strengthen provision of insurance in case of crop failure is among the mechanisms used by farmers, governments and private organizations.

The first priority is to enhance or build the capacity of different stakeholders in the river basin, including water sector and water influencing sectors such as agriculture and livestock, mining natural resources and other related to adapt. For sustainability a combination of sustainable livelihood, innovation systems and learning alliances can be applied in shared basins as indicated in Figure 8.9.

It shows an integrated approach that is suitable for strengthening the capacity of different individuals to adapt to the challenges and opportunities arising from climate change and variability. Vulnerability in this context is determined by shocks, trends and seasonality which to a large extent affect the livelihood of communities differently depending on existing social infrastructural and networks, financial status, human and social capital and natural resources endowments. Better

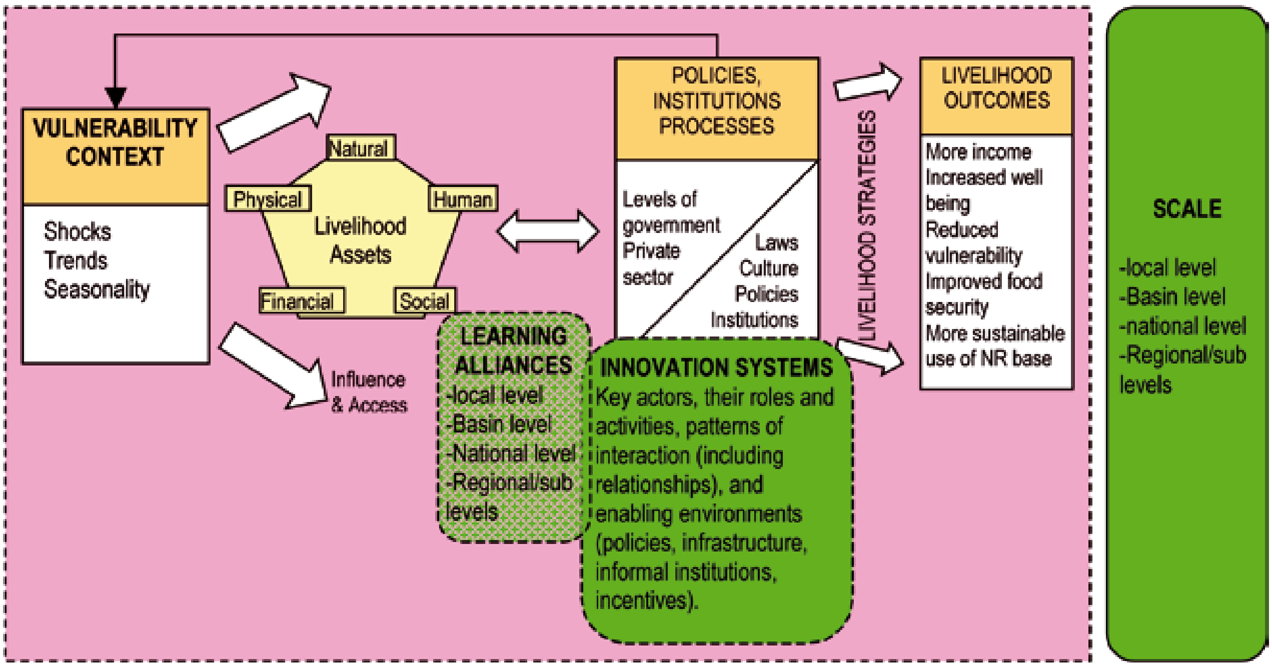


Figure 8.9: A framework for strengthening capacity to adapt to climate change and variability within agriculture system at basin level.

Figure 8.10: Enhance or build the capacity of different stakeholders in river basin to adapt

outcomes could only be achieved via proper policies and laws at various levels to govern proper utilization of resources. This alone, however, makes very little impact on adaptation. What is required is to clearly identify an innovation system at local level that will engage different stakeholders with different roles such as NGO, private sector, researchers, policy makers and also proper infrastructures such as transport, marketing and storage structures in order to enable the system to function properly. Within the framework of the learning alliance, people will be able to learn and share experiences on adaptation which will enable up-scaling of innovations. The framework depicted in Figure 8.9 is relatively straightforward to understand and increasingly well-known. It helps to engage with stakeholders with different perspectives in debate about the factors that affect livelihoods, their relative importance and the way in which they interact. This, in turn, should help in the identification of appropriate entry points for capacity strengthening to adapt to climate change and variability in the agricultural sector.

The project on strengthening local agricultural innovation systems to adapt to climate change and variability being implemented in Tanzania and Malawi in Tanzania is a good example that can be adapted and shared. The project takes on board different stakeholders within the sector to strengthen adaptations including local farmers, extension workers, private sector, NGOs, policy makers and researchers. The project started in 2007 and will continue until 2011. Initial findings based on the situation analysis conduced recently are presented in Table 8.2.

In general, climate change and variability is not a new phenomenon to the local communities living in the low and high potential areas of Tanzania and Malawi. Low potential areas aredefined as having an annual rainfall of less than 600 mm per annum, having one growing season, poor soils mainly highly weathered ferrasols, limited social infrastructures and lack of permanent rivers. High potential areas have a suitable natural environment, for example, more rainfall (700 to more than 2000 mm per annum), well established social infrastructure and networks, 2 or more growing seasons, existence of permanent rivers and other sources of water. The summarized information in Table 8.2 shows that communities living in low potential areas are the most vulnerable to climate change and variability, compared with those living in the high potential areas. However, vulnerability is not the same and is determined by a number of factors including the wealth, age and gender of an individual. A range of possible adaptation strategies are already in place, what is needed now is to critically assess them and find a way of improving them. In this case, crop irrigation seems to be one of the best options and the type to be adopted should reflect different types of water sources. For example in semi arid basins, water storage dams could be developed in particular chaco dams. In high potential areas and transboundary shared water, large scale irrigation projects could be developed to benefit more than one country.

There are a number of opportunities emerging from climate change and variability impacts. For example in the agricultural sector, chances for introducing other non food crops in particular bio-fuel plants which are most adapted to our local environment could improve the livelihood of communities through sale. This needs to be properly planned in order not to exasperate the current world wide food crisis. Yet, the existence of potential shared water sources from different basins such as Congo, Nile, Ruvuma, Rufifi, Kagera and other rivers could be tapped and used to develop agriculture in a number of ways. In this case, a cooperation between developed and developing countries is highly needed bearing in mind that climate change impacts is a global issue.

5.3 Climate change-human-environment-interactions

River basins are potential source of livelihoods in Africa. Such basins are now subject to a number of natural and human induced threats which posses a serious problems on productivity and sustainability of different resources in particular water. Agriculture is currently been seen to be mostly affected. In order to come up with some solutions to mitigate the problems, the author has been able to articulate threat, causal factors and possible negative impacts as indicated in Table 8.3. This applies for both shared and non shared trans boundary basins.

Country	Tanzania		Malawi	
Perceptions and changes	**Low potential area**	**High potential area**	**Low potential area**	**High potential area**
	• climate (temperature, rainfall, wind, whirl wind) • temperature increasing • rainfall decreasing more unpredictable • rainfall coming late and ends soon	• climate (temperature, rainfall, dew, wind, lightning) • high temperature starts early, cool period increased • rainfall came late and unpredictable • dew decreasing	• climate (temperature, rainfall, wind, whirl wind) • temperature increasing • rainfall decreasing more unpredictable • rainfall coming late and ends soon • unpredictable floods	• climate (sunshine, rainfall, dew, coldness) • high temperature starts early • cool period extended • rainfall came late, unpredictable • dew decreasing
impacts	• declining crop yield • traditional crops abandoned • poor livestock production • increasing livestock diseases (ecf)	• decline soil fertility • stunted crop growth • destruction of mature crops in the field and stored ones due to shift of rainfall	• increasing hunger periods • increasing dependency on natural resources • loss of human property due to floods	• landslides and soil erosion • crops damaged • animal loss due to floods • increasing malaria
vulnerability	• the poor in the community • women, children, and elders are the most vulnerable • people with less education • disabled and sick people • crop growers and livestock keepers	• the poor are most vulnerable • women, children, elders are the most vulnerable	• the poor vulnerable • women, children, elders, sick people • communities living in flood plains • communities in areas with poor infrastructures • areas with less social network • coomunities living in flood plains	• the poor are most vulnerable • women, children, elders are the most vulnerable
adaptations	• use drought resistant crops (eg sunflower) • small scale irrigation of crops • increasing non farm income generating activities • use of appropriate crop varieties (early maturing) • introduction of new crops	• increasing wetland farming • improved social networks • use of improved seed varieties • use of artificial fertilizers • networking	• increased sunflower, cassava cultivation • traditional irrigation of crops in dimba • improve agronomic practices • increasing non farm income generating activities	• increasing increasing dimba farming • strong social networks • well established institutions • communication well established

Table 8.2: A comparison analysis of climate change issues between Tanzania and Malawi

Source of threat in Basin	Causal factors	Possible negative impacts
Expansion of wetland farming	Food and income insecurity associated with declining dry land productivity	Drying of wetlands and impaired water hydrological cycles, loss of water regulatory functions
Increased exploitation of forest wood products	Rising demand for energy and wood products	Forest degradation and fragmentation, loss of ecosystems functions, weakening of hydrological cycles
Cultivation nears rive banks	Decreasing soil moisture associate with drought and soil fertility loss	Siltation of rivers thus reducing river flows, water pollution
Increasing livestock numbers	Raising demand for protein and tourism, increasing demand for suitable grazing areas during dry season	Conversion of forest into grassland and thus increasing GHG
Use of non wood forest products	Demand for food and income, medicines and cosmetics	Severe flood impacts due to loss of vegetation cover, rapid loss of genetic pool and biodiversity

Table 8.3: Most significant threats to resources associate with climate change and variability

6. Sustainability of Water Resources in Basins

For effective utilization of transboundary shared water resources, a proper approach needs to be identified and put in place considering a number of issues such as; i) Reviewing existing international and national policies on water and environment; ii) Review existing national development program and set up of river and lake basins so that harmonization can be made; iii) take an inventory of available surface and ground water resource to enable effective planning water resource management; iv) considering downstream/upstream relationship as well as disparities on water resource endowments per country, there is an urgent need for establishing a proper mechanism for sharing benefits accruing from use of water resources; v) improving the management of climate data including collection, analysis and dissemination of rainfall and temperature data is so important in managing water in river basins.

IWRM concept needs to be put into operation at this juncture as it addresses a number of issues with regards to water use for both livelihood and ecosystems. In order to make sure that water resource is well managed at different levels, there must be proper water policies and legislations that govern water resource use, both trans boundary and non shared water course. For regional shared water resources, regional integration become a critical issue for example the Nile Basin Initiative which has an element of shared vision regarding the use and management of water resource by giving equal opportunities for the ten riparian countries that share the Nile water. Lake Victoria Environmental Management Program (LEVEMP) has also been in place to make sure that water resource in Lake Victoria basin is well management and utilized for the benefit of all countries that share the basin (Tanzania, Kenya and Uganda). On the other hand, the SADC water policy and strategy create an opportunity for SADC countries to implement transboundary water management projects in the regional on mutual benefit basis.

On the other hand, for effective use and management of the water resources, reforms taking place in Tanzania where by river basin authorities have been given a mandate to manage water resources at basin level, it has been able to involve different stakeholders from water sector such as agriculture, wildlife, forest and mining. Water pollution is also another threat apart from climate change impact and this need to be taken into consideration. Different communities for example in Great Ruaha Sub Catchment in Rufiji Basin, Tanzania have established a number of water user associations and one of their responsibilities is to formulate by laws that governs water allocation and use as well as well as sustainable water use practices such as setting an appropriate distance for human activities from the water source. For example it is illegal to cultivate in the water source or within wetlands. It is important to ensure that proper water management practices be followed based on research and consultations in order to sustain water resource.

7. Conclusions and Recommendations

The economies of southern Africa are largely dependent on climate-sensitive sectors such as agriculture, hydro-power dependent industry, fisheries, forestry, wildlife and tourism all of which heavily depend on water resources. The poor in the region depend extensively on natural resource utilization and dry-land agriculture as key livelihood strategies, making them particularly vulnerable to climate change. Climate change is a reality and has now become an additional threat (population and economic growth are also some of the drivers) putting pressure on already stressed hydrological systems and water resources, including water quantity and quality. Climate change is anticipated to have far reaching effects on the sustainable development of developing countries including their ability to attain the United Nations Millennium Development Goals, since water is central to achieving many of the MDGs, including food security, health and energy as some examples. Africa and southern Africa in particular, is being significantly affected by climate change given the extent of the change and the vulnerability of the region. However local community have been adapting differently to climate change differently. The adaptation measures needs to be valued and strengthened in order to cope with rapid climate changes.

For transboundary shared water resources, the following needs to be done; i) harmonization of existing and national policies and strategies on water and environment in the management of transboundary waters; ii) integrating existing national development program in shared basin; iii) sharing information on water resources across the boarders.

Integrated Water Resources Management promotes cross-sectoral efficiency and cooperation at all levels on sustainable water resources development and management, including specific sector interventions. In relation to Climate Change Adaptation, an IWRM approach should be followed.

Action research on agriculture needs to be promoted taking on board different stakeholders in order to build their capacity to adapt and hence improve food security at all scales (local, national, regional and global). This is important because climate change is not site specific.

References

AIACC (2006). Climate Change Induced Vulnerability to Malaria and Cholera in the Lake Victoria Region, A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. AF 91 the International START Secretariat 2000 Florida Avenue, NW Washington, DC 20009 USA, available at www.start.org

Blvd, W. (2006). Coping with Global Climate Change: The Role of Adaptation in the United States, Pew Center on Global Climate Change. Suite 550, Arlington, A 22201, (703) 516-4146.

Devereux, S. and Edwards, J. (2004). Climate change and food security. IDS Bulletin 35 (3): 22-30, Brighton, Institute of Development studies.

Downing, T. E.; Ringius, L.; Hulme, M. and Waughray, D. (1997). Adapting to Climate Change in Africa. Mitigation and Adaptation Strategies for Global Change 2:19-44.

Eriksen S. (2001). Linkages between Climate Change and Desertification in East Africa Part 2: Policy linkages between climate change and desertification. http://ag.arizona.edu/oals/ALN/aln49/eriksen-part2.html retrieved on June 2006.

Feenstra, J. F., Burton, I., Smith, J. B., Richard, T. S (1998). Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies, United Nations Environment Programme and Institute for Environmental Studies vrije Universities Amsterdam, Version 2.

Galvin, K. A.; Boone, R. B.; Smith, N. M. and Lynn S. J. (2001). Impacts of climate Variability on East African pastoralists: Linking social science and remote sensing. Climate Research 19:161-172.

Galvin, K. A.; Thornton P. K; Boone R. B. and Sunderland, J. (2005). Climate Variability and Impacts on East African Livestock Herders, International Livestock Research Institute, Nairobi, Kenya

Garcin, Y.; Williamson, D.; Taieb, M.; Vincens, A.; Mathé, P.-E. and Majule, A. (2006). Centennial to millennial changes in maar-lake deposition during the last 45,000 years in tropical Southern Africa: Lake Masoko, Tanzania. Elsevier B.V. available at www.sciencedirect.com

Garcin, Y.; Williamson, D.; Bergonzini, L.; Radakovitch, O.; Vincens, A.; Buchet, G.; Guiot, J.; Brewer, S.; Mathe, P.-E.; and Majule, A. (2006). Solar and anthropogenic imprints on Lake Masoko (southern Tanzania) during the last 500 years. Springer Science and Business Media (B.V. 2006), CEREGE, France.

IPCC (2001). Climate Change 2001. Impacts, Adaptation Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Geneva: UNEP/WMO. Available at www.grida.no/climate/ipcc_tar/w82/642.htm

Kates, R. (2000). Cautionary tales: Adaptation and the global poor. Climatic Change 34: 5-17.

Low, P. S. (2005). Climate Change and Africa. Cambridge University, New York.

Magana, F. P., Kiwasila, H. L., Juma, H. I. and Butterworth, J. A. (2003). Implications of Customary Norms and Laws for Implementing IWRM: Findings from Pangani and Rufiji Basins. Tanzania. Water Symposium, Gaborone.

Majule, A. E., Gibson, R. and Chiwatakwenda, A. (2007a). Climate Change Adaptations in Low Potential Area of Tanzania: Local perceptions, vulnerability, current adaptations and in future strategies in Maluga Village, Iramba, Singida. CCAA-Tanzania, Malawi Working Paper No. 1

Majule, A. E., Gibson, R. and Chiwatakwenda, A. (2007b). Climate Change Adaptations in Low Potential Area of Tanzania: Local perceptions, vulnerability, current adaptations and in future strategies in Sanjaranda Village, Manyoni, Singida. CCAA-Tanzania, Malawi Working Paper No. 2

Majule A. E., and Mwalyosi, R. B. B. (2005). Enhancing Agricultural Productivity through Sustainable Irrigation. A case of Vinyungu Farming System in selected Zones of Southern Highlands, Tanzania. A chapter in Social and Environmental Impacts of Irrigation farming in Tanzania: Selected Cases: Edited by H. Sosovele, J. Boesen and F. Maganga. Dar es Salaam University Press. ISBN 9976 60 431 9

Majule, A. E.; Mbonile, M. J. and Campbell, D. J. (2008). Ecological Gradients as a Framework for Analysis of Land Use Change, Michigan State University., LUCID African Journal of Ecology (In press).

Martin, P. J.; Topper, C. P., Bashiru, R. A.; Boma, F.; De Waal, D.; Haries, H.; Kasuga, L.J.; Katinila, N.;

Kikoka, L.P.; Lamboll, R.; Maddison, A.; Majule, A. E.; Masawe, P. A.; Millanzi, K.J.; Nathaniels, N.Q.; Shomari, S.H.; Sijoana, M.E. and Stathers, T. (1997). Cashew nut production in Tanzania: Constraints and progress through integrated crop management. Crop Protection 16:6-14.

NAPA (2005). National Adaptation Programme of Action 2005. United Republic of Tanzania, Vice President's Office, Division of Environment, Dar es Salaam.

NEPAD (2003). Comprehensive Africa Agricultural Development Programme (CAADP), Midrand: New Partnership for Africa's Development

Olmos, S. (2001). Vulnerability and Adaptation to Climate Change: Concepts, Issues, Assessment Methods. Available from the Climate Change Knowledge Network web site, www.cckn.net

Orindi, V. A. and Murray, L. A. (2005). Adaptation to Climate Change in East Africa: A Strategic Approach, iied, Gatekeeper Series 117.

Pew, C. (2006). http://www.pewclimate.org/global-warming-in- depth/all_reports/adaptation/index.cfm retrieved on October 12, 2006

Thirtle C., Irz X., Wiggins S., Lin L., and McKenzie-Hill C. (2001). Relationship between changes in Agricultural Productivity and the Incidence of Poverty in Developing Countries. Paper prepared for DFID.

Van Koppen, B., Sokile, C.S., Hatibu, N., Lankford, B.A., Mahoo, H. and Yanda, P.Z. 2004. Formal Water Rights in Rural Tanzania: Deepening the dichotomy? International Water Management Institute Working Paper 71.

Whyte, I. (1995). Climate Change and Human Society. Arnold, London, and New York.

Yanda, P.Z., Majule, A.E. and Mwakaje, A.G. (2006). Wetland utilisation, poverty alleviation and environmental conservation in semi arid areas of Tanzania – The case of Singida Region, Tanzania. Proceedings of East Africa "Integrated River Basin Management" Conference Held on 7th-9th 2005 at ICE Hall, Sokoine University of Agriculture Morogoro, Tanzania

United Republic of Tanzania (2003). Initial National Communication under the United Nations Framework Convention on Climate Change (UNFCCC). Vice President's Office, Dar es Salaam, Tanzania

Chapter 9

Quantifying the Costs, Benefits and Risks associated with Climate Risk for Water Resource Development

Planning and Management Alternatives associated with Berg River Catchment Area Case Study (South Africa) – Moving Best Samples into Good Practice

By Peter Johnston, DB Louw, O Crespo and TG Lumsden. University of Cape Town. Rondebosch 7701, South Africa.

Contents

1. Introduction

The Western Cape Province is an extremely important region for the economic development of South Africa. It is South Africa's most valuable agricultural producing region and makes a substantial contribution to the country's balance of payments. Almost all of the land that is farmed in this region is under irrigation. In recent years, the economy of the region has received an added stimulus from tourism, with visits to Cape Town from Europe, Asia, and North America growing at an annual rate of over 10 per cent.

Figure 9.1: The study area, showing water transfers

Growth in the tourism industry has created a boom in the local building industry and this growth has been supplemented by equally rapid growth in the construction of vacation and retirement housing.

Not surprisingly, the population in Metropolitan Cape Town and a number of smaller cities in the region is also growing rapidly, swelled by the demand for jobs in the construction and services industries related to tourism. As this has happened, the demand for water in Metropolitan Cape Town has increased around 4 per cent per year over the past decade and more than tripled since the late 1970s (Louw and Van Schalkwyk, 2001). Increasing competition for water has resulted in the construction of a number of smaller water storage reservoirs in the past twenty years (fig. 9.1-2). The Berg River Dam, with a storage capacity of around 130,000 cubic metres has recently (2008) been completed and more storage reservoirs are on the drawing boards, but the number of suitable dam sites left for development is quite small, as is their

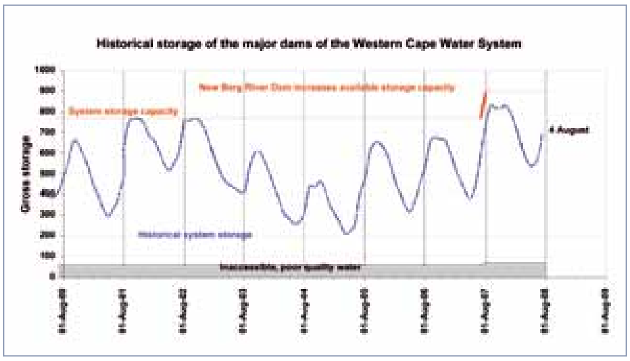


Figure 9.2: Irrigation dam levels

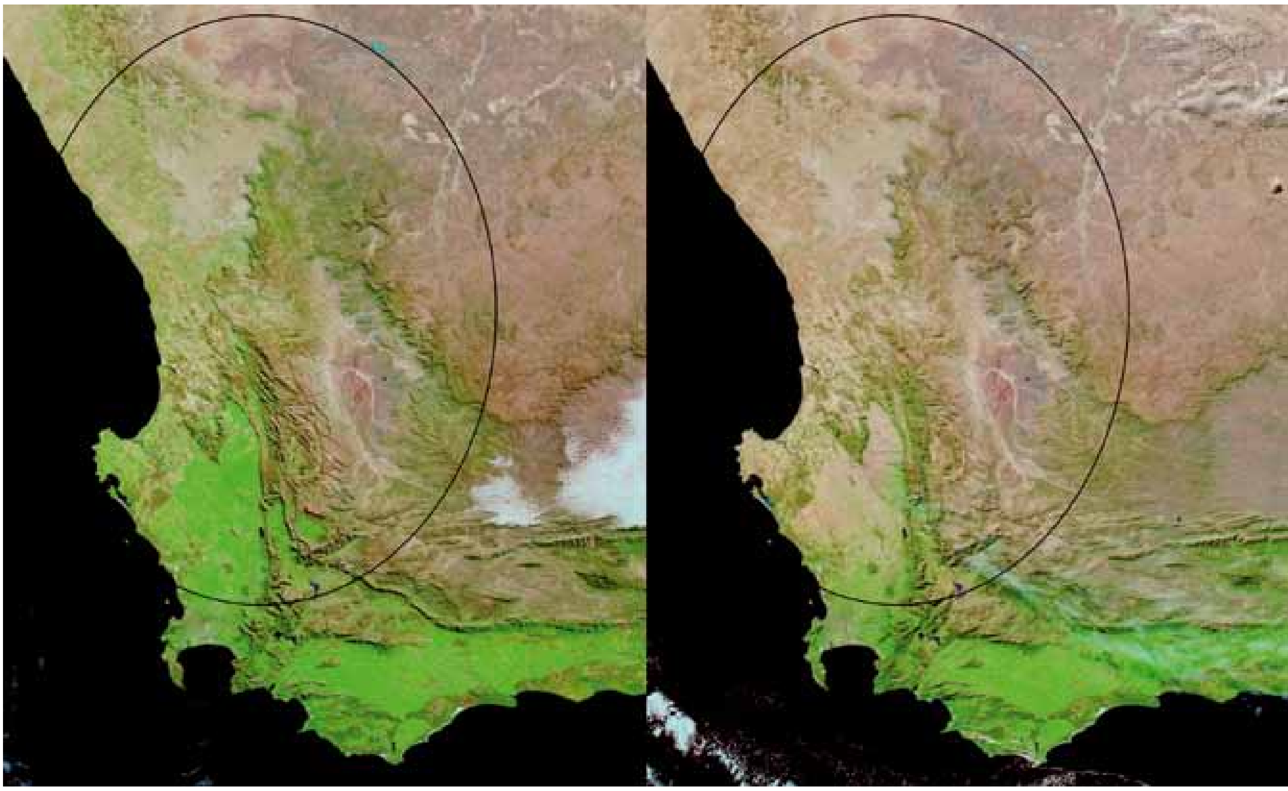


Figure 9.3: Water is an already scarce resource in the Western Cape (left: 21 July 2002 - Normal; right: 21 July 2003 - Drought)

total storage capacity. Desalination and groundwater usage are two alternative options which are being investigated, but the former is currently still prohibitively expensive and the latter is not well understood and very likely being overexploited already.

Against this backdrop of rapid water demand growth and increasing competition between agricultural and urban water users, are the issues of local climate variability and climate change. The climate of the Western Cape can be characterised as a Mediterranean climate, with most of the rainfall occurring during the winter months from April to September. It is one of the few regions to demonstrate consistent projections of changes in climate under the IPCC scenarios. These scenarios suggest a reduction in future winter rainfall, which will exacerbate an already water-stressed region (fig 9.3 -9.6) On top of this, the region has experienced a series of unusual droughts in the past decade, the most recent of which, during 2004–2005, leaving the region critically short of water, resulting in a roughly thirty per cent decline in irrigated agricultural production in the Berg River basin and forcing Cape Town and other smaller local municipalities in the region to introduce water rationing. At present it is unclear whether these droughts are a consequence of climate change or multi-decadal climate variability. Although they are projected to occur more frequently in scenarios of future climate change, these droughts potentially result from the combination of variability on both multi-decadal and longer time scales. Early in the 20th century, drought periods of up to 6 consecutive years occurred, stimulating the search for new sources of water. This demonstrates that persistent drought conditions are not new. If climate change leads to an increased frequency of drought years, the statistical possibility of a crippling drought of 3 years or longer will increase.

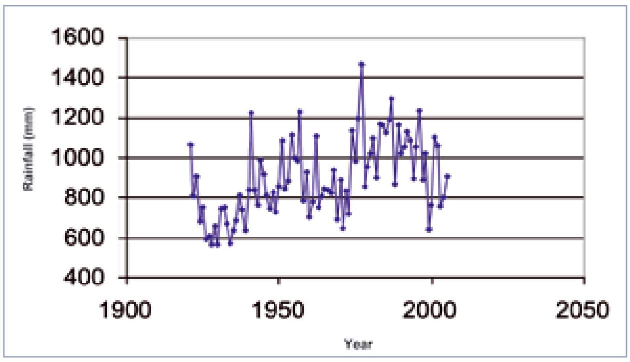
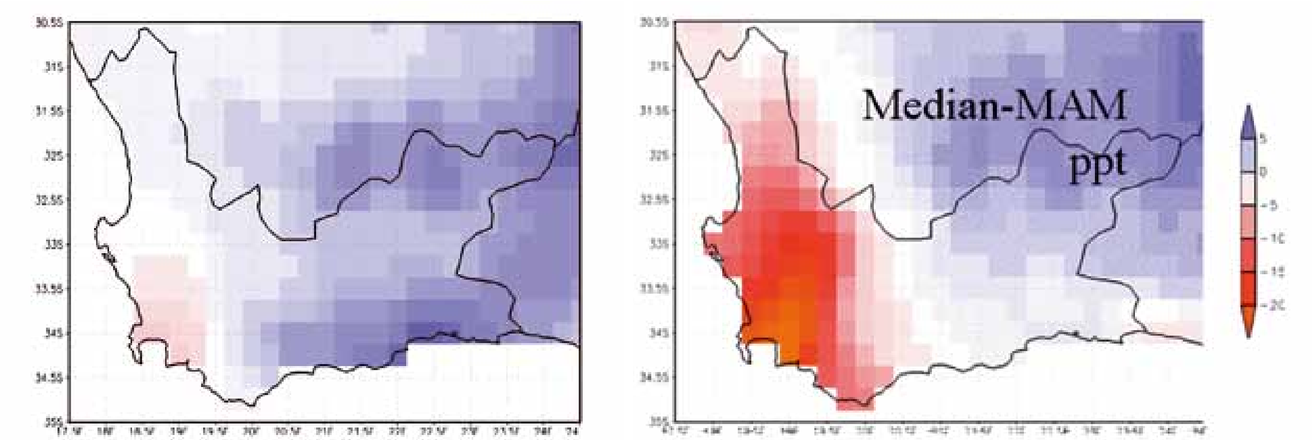


Figure 9.4: South WC annual rainfall: The 1920s saw a severe, sustained drought - Vulnerability to variability

Finally, the regional picture is further complicated due to the socio-economic realities and priorities at the municipal, provincial and governmental levels. As previously stated, the Western Cape is currently undergoing rapid population growth. Much of this is due to high rates of immigration, largely of relatively poor peoples who arrive in search of employment opportunities, and who tend to settle in the poorest townships. The consequent increased competition for water is the result of a two-edged sword, as the agricultural and urban services sectors provide livelihoods for the rural population as well as con-



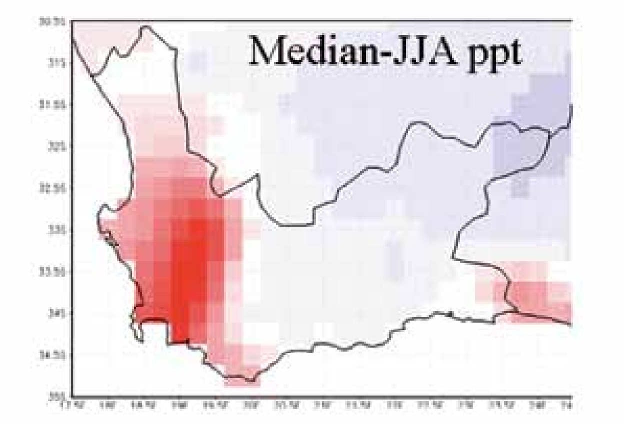


Figure 9.5: Projected Rainfall - 2035

tributing to the local economy.
Since 1994, following the election of a democratic government in South Africa, a new strategy of land reform was initiated with the objective of transferring at least 30% of the available agricultural land in the country to previously disadvantaged individuals (PDIs). Although the process has been slow, most of the successful land reform projects in the Western Cape have been in the fruit and wine industry. According to most climate change estimates, the deciduous fruit sector, dependent on chill units in the dormant months for quality fruit production, will be the most vulnerable due to increases in winter temperature. It is therefore of paramount importance to develop adaptation strategies for these new, mainly resource poor farmers as well as for small scale farmers who rely on agriculture to supplement meagre incomes from elsewhere.

It is evident that an approach which integrates climate, water, the economy and local development agendas is required by scientists, water resource managers and users to ensure the long-term sustainability of water to all parties and practices.

A tool, the Berg River Dynamic Spatial Equilibrium Model (BRDSEM), that can estimate and compare the benefits and costs of projects in natural resource sectors designed to reduce the expected damages from climate change, has been developed for the water sector (Calloway et al., 2005). Well-established principles from economic benefit-cost analysis were used to develop a framework to estimate the economic benefits and costs from the expected climate change damages avoided by a development project that does not take climate change into account. These benefits and costs were then compared with the case where planners incorporate expected climate change into the project assessment. The second part consisted of demonstrating this methodology on a selected adaptation project. The area selected for the project was part of the Berg River catchment in the Western Cape Province of South Africa.

Results indicated that although substantial benefits were accrued from irrigation at a macro economic level, increased income from irrigation was not matched by costs incurred by farming households, suggesting the need for further policy measures to support irrigation. This is all the more relevant given a variable economic situation, triggered mainly by low exports and increasing imports. Further, given the potential impacts of climate change and extreme weather conditions on countries with surplus production, and the risk of those countries reverting to scarcity economics, especially in low production years, countries are better-off growing their own food than expecting to meet their demand from imports. The social impacts of re-vitalised agricultural production on employment generation, alleviation of poverty (including increased income, improved nutrition of women and children), rural regeneration and development etc., cannot be over-emphasised.

Overall, the analysis of the costs of caution and precaution did not provide any unambiguous results that would allow one to determine if it would be cheaper to anticipate climate change or plan cautiously (Calloway et al., 2005).

It was suggested that further research expand the study area to include the entire Berg river catchment area. This encompasses the metropolitan areas of Cape Town and numerous satellite towns between the Cape Fold Mountains in the east and the Atlantic Ocean in the west. It would also be necessary to update the climate change projections and integrate them into a more applicable hydrological model, and finally to apply a socio-economic analysis to quantify the costs, benefits and risks associated with climate change induced runoff impacts. Such a study would represent an important step in bridging the communication and data gap between climate scientists and water planners, allowing water planners to work with climate change data on essentially the same basis that they work with observed climate records, while taking into account the inherent reliability problems in existing global and regional models to reproduce the 'historical' climate.

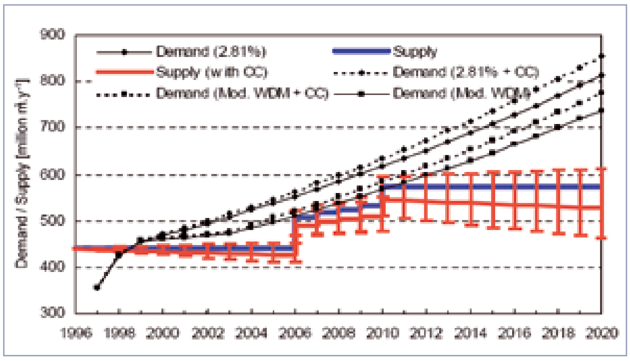


Figure 9.6: Western Cape water supply vs. demand (with climate change)

2. Problem and Objectives

This paper focuses on the progress and recommendations of an ongoing research project to address two significant problems related to adaptation to climate change in the water resources sector of African countries.

The first is that relevant and important information from climate change projections is not being disseminated adequately to water resource managers, nor is it being integrated into water resources policy, planning and management in a systematic way for agricultural and human use in Africa.

The second problem is that there is currently a shortage of integrated approaches for evaluating and making adaptation decisions related to water resources in Africa. Taken together, the lack of awareness and capacity to adapt gives rise to the following priorities and thus objectives of the study:

1. To develop and demonstrate the quantitative and qualitative tools and methods required to conduct integrated assessments of adaptation decisions vis-à-vis climate change and climate variability.
2. To develop the capacity of South African and regional (Western Cape) institutions in the private and public sectors to better integrate information concerning climate change and climate variability into water resources policy, planning and management.
3. To demonstrate how this information can be used to evaluate alternative strategies and projects for adjusting/adapting to climate change and climate variability for application in other regions (where these will include adaptation strategies for resource-poor and emerging farmers).

3. Methodology

The approach used is to link the defined specific objectives with six clear tasks, or work elements, and their associated sub-objectives in the following manner:

- Capacity building and stakeholder integration
  Task 1: Capacity Building – Stakeholder workshops and training
- Development/refinement of assessment methods
  Task 2: Extension of the geographic coverage from the Berg River to the Cape Winelands (Boland) district
  Task 3: Improvements in the global-regional climate interface and regional climate projections and forecasts
  Task 4: Improvements in the capability of water resource managers to assess adaptation strategies and options
  Task 5: Development of scenarios and adaptation alternatives
- Assessment of adaptation strategies
  Task 6: Assessment of adaptation options and valuation of climate forecasts

Specific actions will be employed to achieve the objectives and tasks:

The first would be to further develop an existing computing framework for the translation of climate to agrohydrological forecasting (lead times ranging from near real time to seasonal) to include multi-decadal climate forecasts and climate change projections. Secondly, it would be necessary to refine existing methodologies employed in the forecasting component of the above computing framework. Subsequently, the ability to represent and select different possible management options/alternatives related to water resources and crop management (parallel activity) would need to be incorporated. Fourthly, the project would need to apply the computing framework to assess the potential impacts of climate variability and climate change on the Western Cape Water System (WCWS). Fifthly, the project would explore possible response strategies (both short and long term) via simulation and consultation with stakeholders (parallel activity) and, finally it would assist in developing the interface between the computing framework and the economic model.

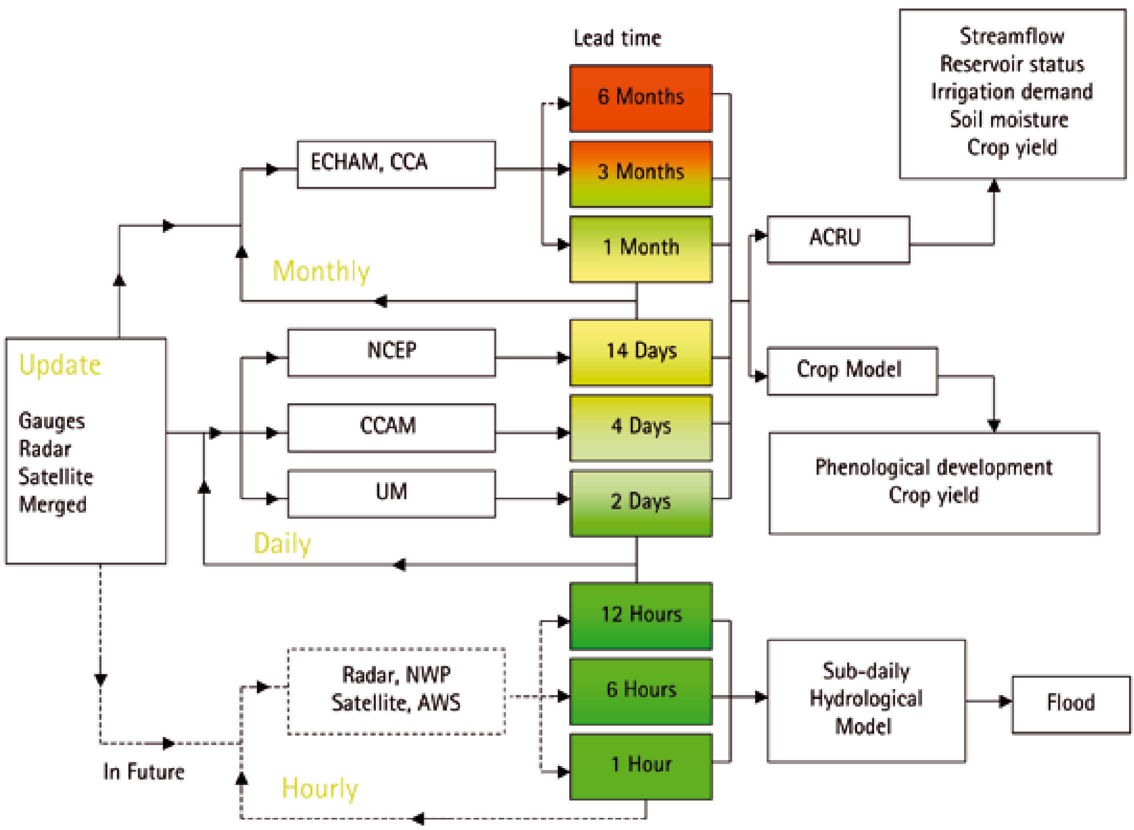


Figure 9.7: Existing Framework

Amongst other things, this will require the modification of the existing computing framework developed by Ghile (2008) to enhance agrohydrological forecasting and to include climate change impacts assessment. Features that will be enhanced or developed in the existing framework include:

1. The ability to 'nest' shorter term climate forecasts within longer term climate forecasts to produce more representative time series of climate for agrohydrological modelling, thus improving longer lead time forecasts. This will require strategies to utilise multiple climate forecast ensembles across a range of forecast lead times and to mitigate against the potential for errors to be propagated.

2. The consideration of the monthly time step stochastically based Water Resources Yield Model and/or the Water Resources Planning Model needed for the modelling of complex water resources systems. Such models could be used in combination with the physical-conceptual daily time step ACRU agrohydrological model (Schulze, 1995; Schulze and Smithers, 2004; Smithers and Schulze, 1995), which is already incorporated into the existing framework.

3. The possible incorporation of the DSSAT suite of crop growth models (to complement the crop yield models already imbedded in the ACRU system) needed for applications such as crop yield forecasting, irrigation scheduling and other crop management decisions.

4. A link to an economic model (run external to the framework by economists) to aid in decision-making processes related to management and planning.

5. The ability to easily represent/select different management options/alternatives in the models included in the framework. A user interface would be provided in the framework for this purpose, thus circumventing the user needing to interface with models directly (the framework aims

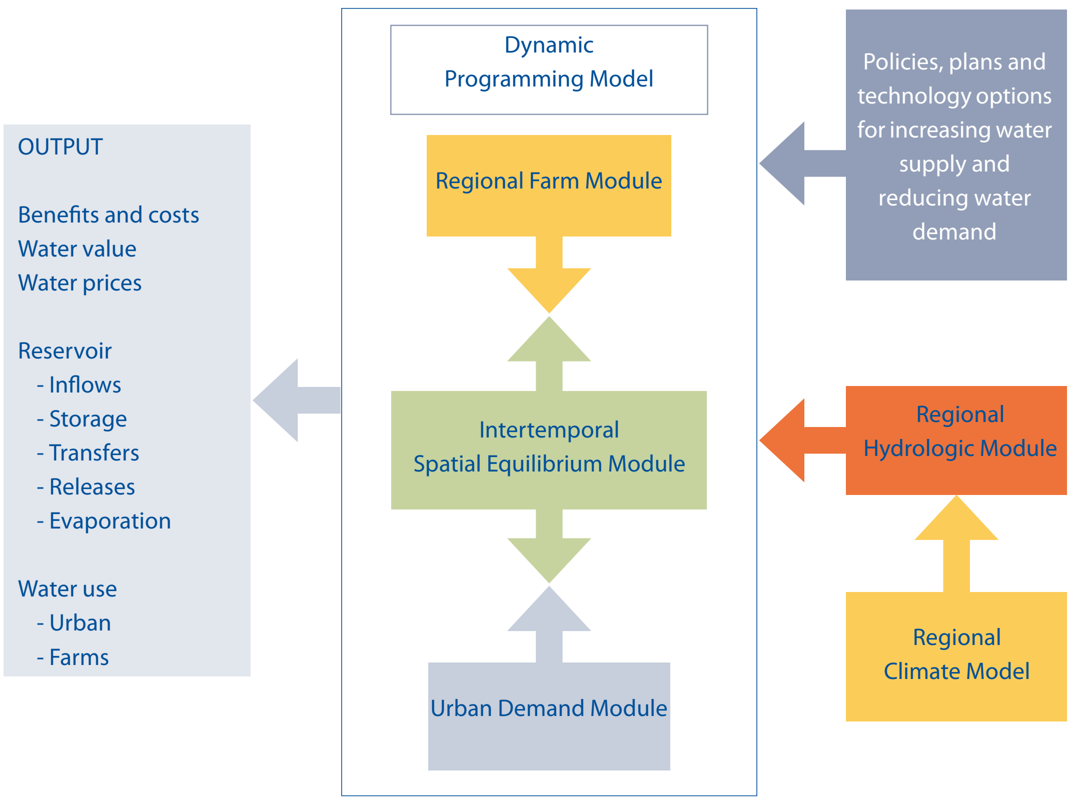


Figure 9.8: Water Resources Planning Model

at minimizing user interaction with the models to simplify the process of performing simulations – particularly needed for operational contexts). The ability to select management options/alternatives would be used in both climate variability and climate change contexts.

6. The ability to incorporate multi-decadal climate forecasts and long term continuous simulations of projected climate change.

Climate change is expected to intensify existing problems in developing countries where communities are directly dependent on the natural environment (Ziervogel et al., 2008). These changes are likely to affect our present and future activities, especially in poor rural regions where adapting to change can be a very slow process. Projected changes in temperature and rainfall will significantly impact agriculture. However, such changes may have either a positive or negative impact, depending on their location and timing. National and regional decision makers are thus looking for adaptation guidelines and decision making tools to help moderate potential impacts in these vulnerable regions. Likely impacts can be simulated using models which simulate the system expected response, subject to future hypothetical climate conditions. Two simulation-based methods will be implemented to do this.

The first aims at analysing the sensitivity of agriculture yields to potential adaptations subject to expected climate scenarios, while the second method aims at providing guidance as to what may be the best adaptation options. Optimization methods, guided by the optimal expected responses under uncertain future climate projections, are used to achieve this objective. Several studies of climate change impacts on agriculture exist, which in general have focussed on selected areas. Walker and Schulze (2008), for example, simulated the changes in yield, risk and soil organic nitrogen levels over three climate regions on the South African Highveld (Christana [relatively dry], Bothaville and Piet Retief [relatively wet]). They conclude that climate scenarios suggest negative impacts within these regions, especially in the drier western areas. Lobell et al. (2008) studied crop adaptation in selected regions around the world using multiple General Circulation Models (GCMs). They concluded that southern Africa is one of the regions that is likely to suffer negative impacts on several staple crops, including maize. These studies have generally utilised climate data from large-scale GCMs and to date no study has explicitly looked at adaptation optimization over the entire South African region using climate data (rainfall and temperature) downscaled from multiple GCM climate change projections using advanced statistical methods.

The latter is the goal of this research, focusing on the current and future implications of climate on agriculture in the Berg River Catchment Area using statistically downscaled climate change scenarios. The primary objective is to extract information on adaptation best practices using sensitivity analyses and optimization methods. The first stage is concerned with enabling decision makers to comprehend the potential significance of adaptation parameters, such as sowing date, irrigation strategy, or crop type/cultivar selection in agriculture, or reservoir storage and operating rules in water resource management, and how they might evolve in the future. The second stage seeks to identify a few optimal adaptation choices, based on current knowledge. The purpose is to produce a range of outcomes and not to select a preferred or specific one. This 'ensemble' of outcomes allows a decision maker to choose the best directions for future adaptation options, based on their knowledge of the particular or local situation being addressed. Combining these methods helps in giving appropriate advice to decision makers on the future impacts and the range of best adaptation options they might consider.

4. Strategies

Each task of the project includes specific strategies that have been developed to fulfil that particular task and to integrate it with the other tasks.

Task 1: Capacity building

Establish and enable a project steering group: A steering committee has been selected, representing water users as well as groups with broader water resource interests, including representatives from: a) National and regional governmental bodies that are responsible for water resources policy, planning, management, water use and the environment, b) industry groups representing agricultural water users (including resource-poor and emerging commercial farmers), c) municipal water utilities, and d) water resource NGOs in the region. The broad objective of the steering group will be to ensure that the research and capacity building activities within this project will be congruent with the interests of the much broader group of national and regional stakeholders with regard to water resources policy, planning, management and water use. Members of this group will have a major say in how they function, in order to motivate their commitment and help establish a sense of “ownership” of the project. Therefore, the specific focus of the group, the process of interacting between the steering group and the project partners, and the methods to be used to achieve a consensus regarding this guidance will be developed jointly by both groups after the project has begun.

Transferring models and methods to, and training of, stakeholders: The developed integrated assessment modelling approach will be extended to the larger and more relevant water resources planning region in the Western Cape. A major reason for doing this is to “hand over” the model, its associated databases, and the capacity to use the model to interested stakeholders so that they can conduct their own assessments of adaptation strategies and options in the region. Building capacity with the right individuals in the stakeholder groups to use the model will require personalised training provided by UNEP Risoe Centre on Energy, Climate and Sustainable Development (URC) on a case-by-case basis where specific local data, needs and priorities will have to be identified. The dangers involved in technology transfer such as proposed above need to be avoided by obtaining the necessary support from local, regional and national government. The need to integrate climate change information into decision-making will be reinforced by the previously completed “Western Cape Climate Change Status-Quo Report” as well as the current “Climate Change Action Plan and Response Strategy”.

Workshops: At least five workshops will be convened under the auspices of this project, two in the Western Cape region, two national South African workshops and one more regional Southern Africa workshop, envisaged for all for SADC members (or other IDRC funded project members).

The purpose of these various workshops will be:

- To bring together managers, policy makers and practitioners in the water resource, agriculture and climate sectors in an effort to assess existing understandings and to discuss modalities of integrating climate change information into planning and management decisions; as well as to demonstrate an integrated planning and management approach to managing present and future climate risk;
- To raise awareness about climate change and variability challenges in the region and how they can be addressed by adaptation;
- To raise awareness regarding the methods for assessing adaptation strategies and projects, focusing specifically on incorporation of risk and uncertainty, estimation of economic benefits and costs of adaptation projects, analysis of equity based policies and tradeoffs with economic efficiency.
- To train selected water resource stakeholders in model application and development; this would be intended as a pilot project for a much larger regional training effort that would hopefully flow from this research project.

Task 2: Extending the geographic coverage from the Berg River to the Cape Winelands (Boland) district

Adapting and improving the BRDSEM model will involve the following activities:

- Developing new farm models: The integrated modelling system currently contains process models of “representative" farms in seven regions. These models determine the amount of monthly irrigation water used in the farm region and calculate the economic value of the net returns to water for each farm. Creating these process models for the new areas requires two steps. First, the project will collect information from farms in the new areas, regarding their cropping patterns, resource use (including water), resource availability, farm production costs and revenues. Next, this information will be used to develop mathematical process models for the representative farms in the new regions and physically connect these farms to the physical flow of water as it is characterised in the model.

- Water balance model verification: One part of the integrated modelling system consists of a water balance model (ACRU – Schulze, 1995; Smither and Schulze, 2004) that is set-up for specific catchment areas so that it can translate spatially differentiated information concerning daily temperature and precipitation into monthly aggregated runoff, reservoir operation and crop water use factors. This activity will involve collecting information about the historical climate (daily temperature and precipitation) and monthly aggregated runoff at different locations in the study area and then using this information to verify that the water balances in the study area can be accurately simulated before the effects of climate change and climate variability on the hydrology of the area can be modelled.
- Characterising the physical system: The original integrated modelling system contains a mathematical representation of the natural and man-made hydrological systems in the entire study area that links water flows over space, water storage, evaporation and water releases in reservoirs, instream flows and water withdrawals for consumptive uses. When the study area is enlarged, this representation will have to be changed to reflect runoff, water storage and water use in the new catchments and the representations of these new catchments will be linked to the existing systems depicted in the model.

Data Collection: As indicated above this task involves two major data collection efforts; collection of farm-level data, and collection of climate and hydrological data.

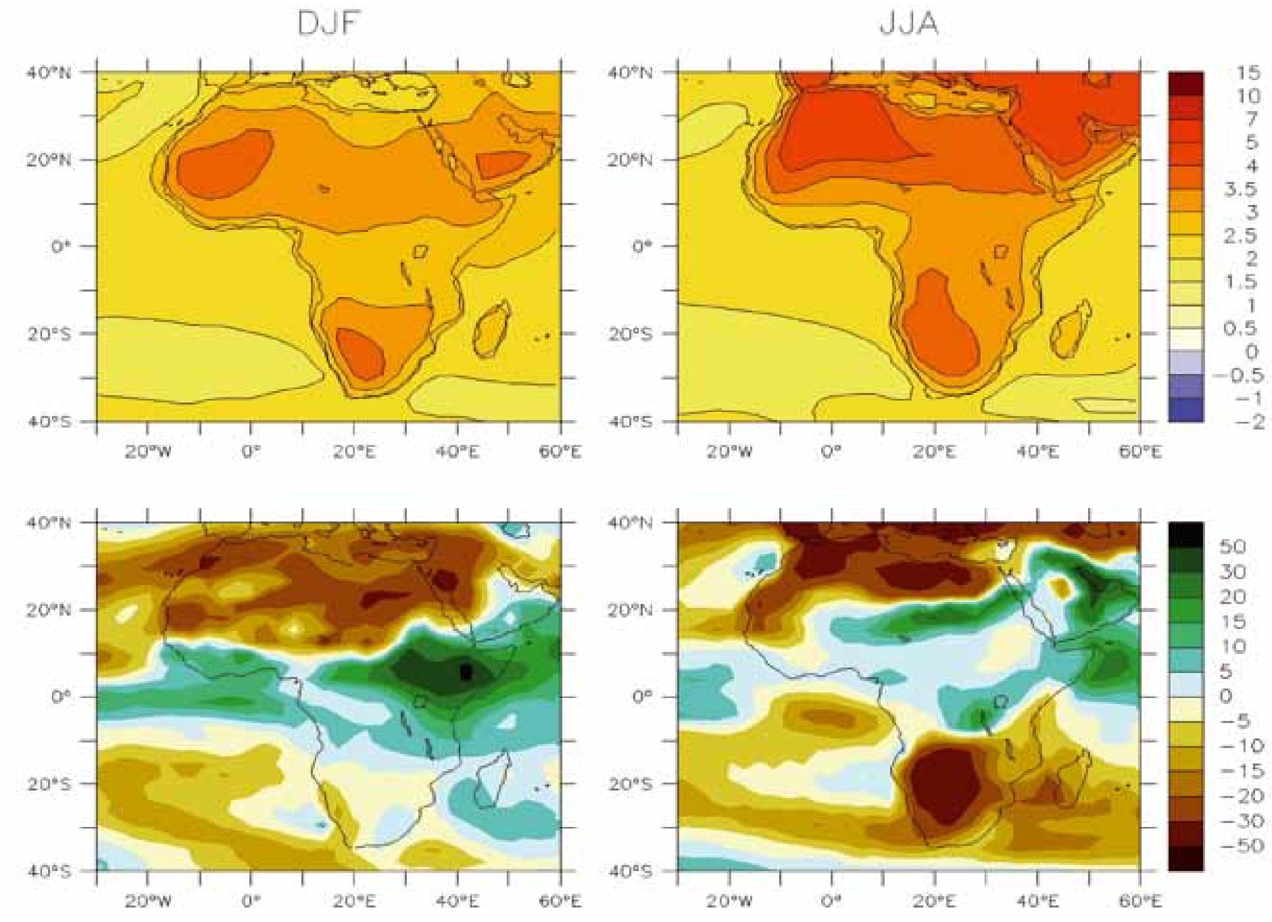


Figure 9.9: Wheater data is critical for climate change modelling

Task 3: Improving the global-regional climate interface and regional climate forecasts

The primary objective of this task is to provide useful and contextualised forecast information for short, medium and long-term decision making time frames. This will be achieved by replacing the linear down-scalings used previously with advanced techniques that are based on the synoptic circulation (avoiding biases in GCM rainfall estimates) and techniques based on the stochastic generation of weather parameters. The former technique will be applied to forecasts at the seasonal, multi-decadal and climate change time scales; taking into considerations the requirements of stakeholders as determined in Task 1. The latter technique will be used to investigate multi-decadal and longer forecasts (longer-term). In particular both techniques will be used to derive probabilistic estimates of change. The specific sub-objectives of this task are to generate downscaled seasonal forecasts on a month by month basis and to downscale multi-model GCM projections of longer-term change (fig. 9.9-12).

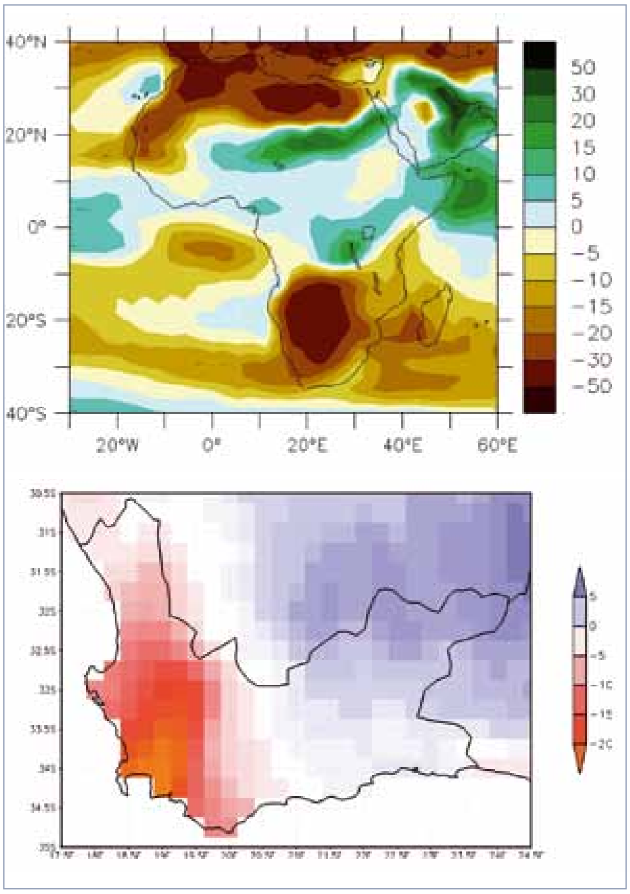


Figure 9.10: Downscaling requires local data

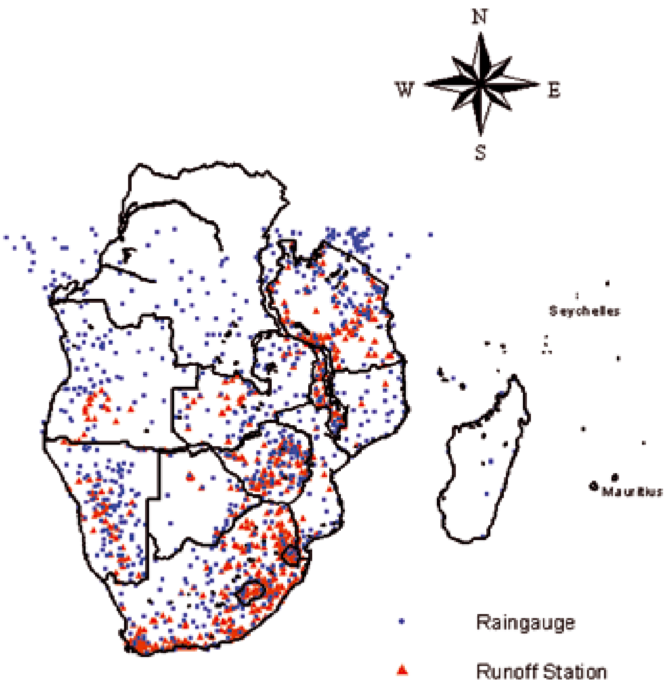


Figure 9.11: Spatial distribution of rainfall and Runoff stations in South Africa

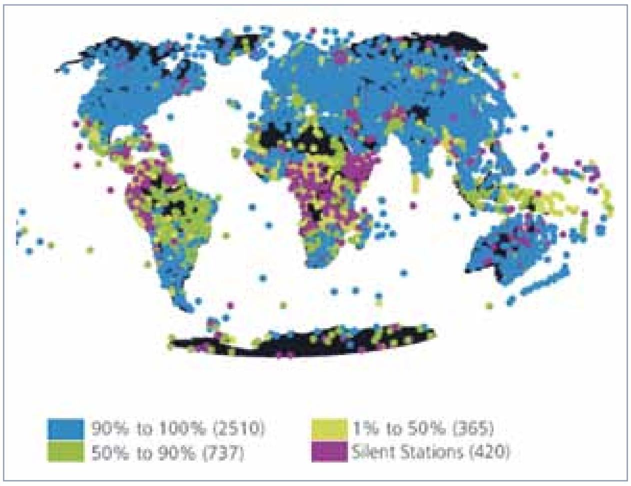


Figure 9.12: Reporting frequency to WMO from World Weather watch stations 1998-2002

Task 4: Improving the capability of water resource managers to assess adaptation strategies and options

The sub-objective of this task is to improve the existing capability developed in the previous project to simulate climate change, climate variability and assess alternative adaptation strategies and projects. In particular this task aims to:

- Improve the characterisation of urban water works supply,
- Improve the characterisation of the demand for water from poorer households,
- Broaden the expectations framework, and
- Improve the ability of the model to characterise climate change.

Callaway (2004) showed how a hydro-economic model could depict climate change in a deterministic, discrete state-space and continuous probabilistic framework. When implemented, the revised integrated river basin model will have the capability to simultaneously simulate numerous climate scenarios, or climate states. It is worth implementing at this time because: a) Access to multi-model downscaled data from GCMs is now available b) information about GCM model biases allow us to construct interval estimates of the physical and economic outputs from the integrated model, with confidence limits around these estimates and c) the ability to simulate the performance of adaptation options and the interactions with system operation over multiple scenarios or climate states is better for analyzing economic factors, assessing risks and selecting adaptation strategies that are more robust.

Task 5: Develop Scenarios and adaptation alternatives

The purpose of this task is to define and obtain the information to develop the operational scenarios that will be used to estimate and compare the value of information about climate change and climate variability and to assess alternative strategies and projects for adapting to climate change. In this respect stakeholder input will again be sought to guide scenario development. In particular the sub-objectives are:

- Economic development scenarios,
- Policy scenarios, and
- Adaptation strategy and project alternatives.

Based on previous experience in simulating climate scenarios using the integrated modelling system, the following types of scenarios will need to be developed in order to conduct these assessments:

- Economic development scenarios - able to isolate the impacts and economic benefits of development/adaptation strategies that have both climate change and development benefits;
- Policy scenarios - information about historical water consumption for all of the classes of urban water users in the mode, and basing our economic development scenarios on these rates, by sector;
- Information for adaptation strategies and projects to be assessed - including new public policies, either proposed or under discussion, that might affect water use in the region, in the assessments of adaptation strategies as they have the potential to influence the impacts of climate change and the physical damages that can be avoided through adaptation strategies and projects; and
- A simulation plan - a plan that most efficiently combines the climate and hydrology scenarios, the economic development and policy scenarios, and the adaptation alternatives in order to assess the physical and economic damages that can be avoided in the study area by adaptation and the extent to which adapting to multi-decadal climate variability complements adaptation to climate change.

Task 6 Assessment of adaptation options and valuation of climate forecasts

This task involves combining the models and scenarios to conduct an assessment that has several new dimensions to which the climate change arena has been infrequently exposed. Typical adaptation assessments focus on estimating the impacts of climate change and then showing how one or more adaptation options will alleviate those impacts. If the assessment is presented in economic terms, then it will also estimate: 1) The economic value of the climate change damages, if there is only short-run adaptation, 2) the economic value of the damages that are avoided by adapting to climate change, after the costs of doing this are removed (i.e. the net benefits of adaptation), and finally,

[1] See, for example: John M. Callaway, 2004. "The Benefits and Costs of Adapting to Climate Variability and Climate Change", Chapter 4. The Benefits of Climate Policy. OECD, Paris Fr. and John M. Callaway, et al. 2006. The Berg River Dynamic Spatial Equilibrium Model: A New Tool for Assessing the Benefits and Costs of Alternatives for Coping With Water Demand Growth, Climate Variability, and Climate Change in the Western Cape. AIACC Working Paper 31.

[2] See, for example, the classic example of valuing El Niño forecasts based on avoided damages by Richard M. Adams, et al. 2003. "The benefits to Mexican agriculture of an El Niño-southern oscillation (ENSO) early warning system." Agricultural and Forest Meteorology, 115: 183-194.

3) the economic value of the climate change damages that are not avoided by adaptation (i.e. the imposed damages of climate change)[1]. In this task two dimensions to the traditional analysis will be added. First, the simulation of the physical and economic impacts of both climate change and multi-decadal climate variability and the assessment of the physical and economic value of the damages avoided by adapting, separately, to both climate change and to multi-decadal climate variability. Secondly, use of the information about the net benefits of adaptation to climate change and to multi-decadal climate variability to estimate the value of both forecasts[2]. Assessment will be made, both quantitative and qualitative, of how useful information about multi-decadal climate variability may be in order to avoid climate change damage, given probabilistic climate change projections.

The sub-objectives of this task are:

- To simulate the effects of climate change and of multi-decadal climate variability on the supply, allocation and use of water in the study area,
- To estimate the economic damages of both climate change and multi-decadal climate variability on different stakeholders in the study area,
- To assess the change in physical damage and their net economic value as a result of adaptation to climate change and multi-decadal variability, and
- To assess the extent to which adapting to seasonal and multi-decadal variability complements measures for adapting to climate change and suggest further measures where necessary.

5. Project Results and Dissemination

There will be three types of outputs from the project:

1. The capability to assess the impacts of climate change and evaluate the performance and economics of adaptation projects in the Cape Winelands District will be embodied in software and the human capital required to maintain, update and use the software for evaluation purpose on an ongoing basis.
2. The more general methodologies and approaches developed in the project to integrate climate change and climate variability into water resources policy, planning, and management.
3. The results of the climate impact and adaptation assessment for the Western Cape

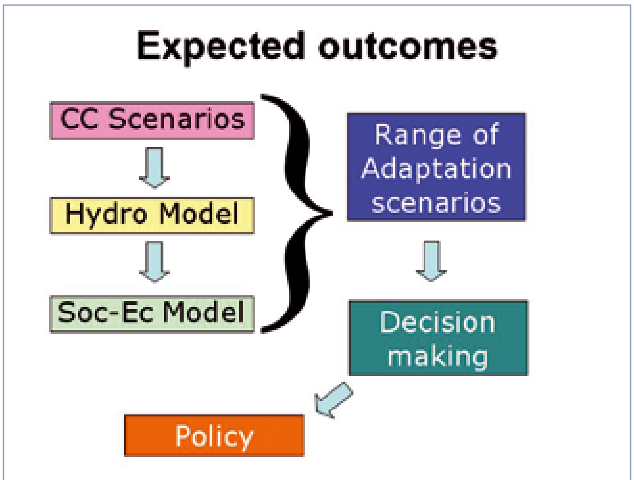


Figure 9.13: Schematic of expected outcomes

The capacity to assess the impacts of climate change and evaluate the performance and economics of adaptation projects in the Cape Winelands District will be transferred to selected South African stakeholder groups in the form of the software, databases and the human capital needed to conduct the relevant climate analyses on an ongoing basis. The latter will be transferred through training sessions by project staff. A "tool kit" will be developed to be used in training which will include, inter alia, the data requirements, how to collect and process data, a basic understanding of the modelling structure and interpretation of the results in the context of adaptation strategies. While a number of groups may want this software and training, it will be important to identify those stakeholder groups who actually have a specific need to implement this capability and have the staff with the requisite background to understand the training they receive.

Information about the methodologies developed for the project, the scenarios and the results of the climate impact and adaptation assessments will be disseminated in different ways:

1. Through the Western Cape, national and Southern Africa workshops to be convened at strategic intervals throughout the project's duration,
2. Through various task reports and a final project report, as shown in the project schedule,
3. Through normal policy discourses and meetings with the stakeholders in the Western Cape and South Africa,
4. Through input to IPCC expert meetings, future assessment reports, and other climate and development bodies on the topic of adaptation costs, as needed,

5. Through working paper and publications developed in the course of the IDRC-CRDI programme, and
6. Through publications in peer-reviewed cross-disciplinary journals covering climate and climate variability issues related to water resources policy, planning and management.

The levels of interest, cooperation and integration that the project has already generated have proved that the progress towards the goals is significant. The ultimate success of the project will be determined by the capacity of the Western Cape Winelands region to survive through the anticipated dry periods and beyond. It is believed that this project will contribute substantially towards a new methodology of managing multi-sector water supply and demand.

The authors gratefully acknowledge the suggestions and comments from the reviewers, and the financial support of the IDRC.

In nature there are neither rewards nor punishments; there are consequences. Robert Green Ingersoll

References

Callaway JM (2004). The Benefits and Costs of Adapting to Climate Variability and Climate Change, Chapter 4. The Benefits of Climate Policy. OECD, Paris France

Callaway JM, Louw DB and Nkomo JC (2005). Capacity Building in Analytical Tools for Estimating and Comparing Costs and Benefits of Adaptation Projects in the Berg River Basin, South Africa (Group AF47). Energy Research Centre, University of Cape Town.

Ghile, YB, (2008). Development of a Framework for an Integrated Time-varying Agrohydrological Forecast System for Southern Africa. Unpublished PhD thesis. School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Lobell DB, MB Burke, C Tebaldi, MD Mastrandrea, WP Falcon and RL Naylon (2008). Prioritizing Climate Change Adaptation Needs for Food Security in 2030, Science 319:607-610

Midgley, G; A Chapman, B Hewitson, P Johnston, M De Wit, G Ziervogel, P Mukheibir, L Van Niekerk, M Tadross, B Van Wilgen, B Kgope, P Morant, A Theron, R Scholes, G Forsyth (2005). Western Cape Government Report: A Status Quo, Vulnerability and Adaptation Assessment of the Physical and Socio-Economic Effects of Climate

Schulze, RE (1995). Hydrology and Agrohydrology. Water Research Commission, Pretoria, RSA, WRC Report TT69/95. pp 552 (ISBN 1 86845 136 4).

Schulze, RE and JC Smithers (2004). The ACRU Agrohydrological Modelling System as of 2002. Background, concepts, structure, output, typical applications and operations. In: Modelling as a Tool I Integrated Water Resources Management: Conceptual Issues and Case Study Applications. Water Research Commission, Pretoria, RSA. WRC Report 749/1/04. 47-83.

Smithers, J and RE Schulze (1995). ACRU agrohydrological modelling system. User Manual, Dept. Agric. Eng., Univ. of Natal, Pietermaritzburg, RSA

Walker, NJ and RE Schulze (2008). Climate change impacts on agro-ecosystem sustainability across three climate regions in the maize belt of South Africa, Agriculture, Ecosystems and Environment 124 (2008) 114-124.

Ziervogel, G, A Cartwright, A Tas, J Adejuwon, F Zermoglio, M Shale and B Smith (2008). Climate Change and Adaptation in African Agriculture. SEI interviewed policy brief.

Website: www.bergriver.co.za

Chapter 10

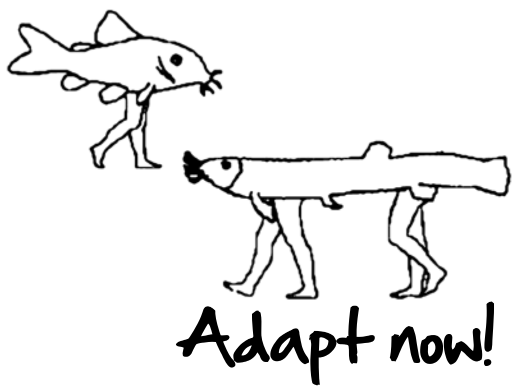
Adapting to Climate Change in Africa: What does it means for household water access and use?

By Gina Ziervogel. Department of Environmental and Geographical Science, University of Cape Town. Cape Town, South Africa.

Contents

1. Abstract

Climate change poses a significant threat to water resources. Yet, in sub-Saharan Africa, few stakeholders at the local level view their access to and use of water from a climate change perspective. One of the groups likely to be most impacted by changes in ther climate are the rural poor. It is urgent that measures be adopted to limit their vulnerability to the impacts of climate change on water resources. Focusing on issues of scale, this paper illustrates how adaptation strategies in the water sector can differ at the household, village, municipal, national or river basin scale in order to reduce vulnerability to climate impacts. To support household access to water, different approaches and perspectives need to be integrated. This requires significant human and resource capacity which is demanding, given the range of other challenges relating to governance, land tenure and quality, high food prices and high levels of poverty that are faced across Africa. A case study from the Limpopo river basin in South Africa is used to illustrate the challenge of focusing on climate change when many other development challenges exist. The study links local village experiences with municipality perspectives and suggests the need to link to river basin organizations to facilitate holistic adaptation in the water sector.



2. Introduction

Adaptation to climate variability is not new, but climate change is expected to amplify existing risk and produce new combinations of risks. This is particularly true in Africa, where direct dependence on the natural environment for livelihood support combines with a lack of infrastructure and high levels of poverty to create vulnerability in the face of all types of environmental change. Accordingly, there is a growing focus on the need for "anticipatory adaptation" (UNDP, 2007), that is the proactive rather than the reactive management of climate change risk.

One of the key climate change impacts in Africa is expected to be experienced in the water sector, with the IPCC stating that by 2020 an additional 75 to 250 million people are projected to suffer increased water stress (IPCC, 2007). This is due to rising temperatures that increase evaporation and a change in rainfall patterns, with reduced annual precipitation in some areas and an increase in others. The impact of climate change on water is going have knock-on effects to livelihoods, ecosystems and food availability (IWMI, 2007). This is particularly concerning at a time when food systems and livelihoods are under increasing stress due to land degradation, rising food and fuel prices, and high levels of poor health.

According to the Africa Commission (2008), water availability in the Niger, Lake Chad and Senegal basins has decreased by between 40 to 60 per cent over the past 100 years. The fact that many of these river basins are shared across countries highlights the need for exploring adaptation strategies that are jointly managed.

Changes in climate, and the resultant impacts on the biophysical and human systems, require us to respond, or adapt, accordingly. Adaptation is an ongoing process inherent in natural and social systems. When faced by changing circumstances, particularly when they become uncomfortable or undesirable, people, like plants and other animals, tend to change the way they are and/or do things so as to survive or benefit from the new conditions. In this sense adaptation is often reactive, i.e. in response to a stimulus, which in turn has knock-on and feedback effects throughout the system.

As we build our understanding of climate change and how it is likely to impact on current systems and practices, the need for investing in planned anticipatory adaptation is increasingly being recognised and acted upon (IPCC, 2007). Whether or not regions, countries, sectors and communities can successfully adapt to climate change will determine whether they are in a position to make the most of any opportunities created as a result of a changing climate, and reduce the extent of likely adverse impacts associated with these changes. In other words, adapting to climate change is critical and needs to be inherent in social and economic development.

The process of adaptation needs to be encouraged, enabled, supported and facilitated by those individuals and organizations in positions to do so; particularly as people recognize the value of proactive (as opposed to reactive) adaptation, i.e. taking action now to avoid unnecessary losses and expenses in the future. In addition to this we recognize that capacity to adapt is not equal among all groups (and neither are the contributions to causing these human induced climate changes) and therefore targeted support is necessary. An adequate response to climate change and climate variability requires focusing on two aspects (as adapted from OneWorld, 2008):

a) increasing and improving people's ability to prepare for, and respond to, extreme weather events (such as more frequent flooding) and increasing climate variability; and
b) investing in mechanisms and systems for adapting to gradual climate change (for example, where overall rainfall patterns in a region change and a particular crop is no longer viable).

Many systems and actors are able to adapt endogenously, and where they have the means to do so it is likely that they will be less vulnerable to climate change impacts. However, many systems and actors are likely to be vulnerable to certain climate impacts and not be able to adapt adequately or rapidly enough themselves. It is therefore important to identify who and what is most vulnerable to climate change impacts so that adaptation support can be appropriately targeted to reach the most vulnerable groups.

Vulnerability has been defined and interpreted in different ways both across and within disciplines (Bohle et al, 1994; Kelly and Adger, 2000, O'Brien et al, 2004; Wisner et al, 2004; Ionescu et al., 2005; Füssel and Klein, 2005). Much of the distinction is tied in with slightly different language usage, with words being used to mean slightly different things, or different words used to mean the same thing (O'Brien et al, 2004). In this paper, vulnerability is seen as the intersection between exposure to a perturbation or stress, either experienced or anticipated, and the sensitivity and resilience of the system to cope, recover or adapt (Turner et al, 2003; Segnestam, 2004; Downing et al, 2006).

It is critical to recognise that definitions and perceptions of vulnerability vary at different scales of analysis. The questions change in different contexts as there are often different factors that are key drivers at different scales. For example, interaction between household members and distribution of economic resources might drive vulnerability to food insecurity at the local scale, yet at the national level, social security policies and implementation relating to grants might be a key driver of food insecurity. Teasing out the role of scalar drivers of vulnerability is complex, yet critical, when deciding how to reduce vulnerability at different scales.

Investigations into the dynamics of vulnerability to global environmental change soon identify that the locale is a large part in determining vulnerability (Kelly and Adger, 2000). Place-based studies are necessary to identify vulnerability. Franklin (2004) distinguishes the general phenomena of vulnerability, in that we are all vulnerable, from the particular aspects that results in some people or places being more vulnerable than others.

3. Adaptation to climate impacts on the water sector at the household scale

Variability and changes in rainfall and temperature patterns impact all aspects of water resources development and management from supply, through distribution to demand. Often, bulk water supply is based on abstractions from large storage dams, which are greatly affected by changes in rainfall amount, its timing and evaporation rates (DEAT, 2004). Where this infrastructure is less developed or insufficient, groundwater extraction is common. In this case, water-table levels and recharge rates are much affected by climatic changes (Bouraoui et al., 1999). Hotter and drier conditions are usually associated with increases in water demand, creating a double impact problem. For these reasons, water is a good lens through which to view impacts of climate change in addition to the fact that everyone requires water for their livelihoods (Schulze, 2008).

Water needs to be examined from both ecological and physical perspectives as well as from social, economic and governance perspectives. The impact of, and consequent response to, climate variability on water resources can be viewed through different lenses. In this paper the focus starts with the manner in which households might adapt to a change in access to and use of water.

If rainfall patterns change, households may need to adapt in a range of ways. If people are involved in agriculture, they might need to change seed varieties or agricultural practices. For example, a shortening in the length of the rainy season might require seeds of more drought resistant cultivars to be used. Conservation harvesting and mulching might help to retain soil moisture if the dry season lengthens. If total precipitation is expected to increase, methods could be explored to ensure that soil does not become waterlogged as easily as before by improving drainage.

Within the household, measures might be needed to deal with longer dry spells. Rainwater harvesting tanks could improve access to water during these times, although they generally only store enough for a few months. More efficient domestic water use could be achieved by using latrines that need less or no water. If there is running water in the household, low flow shower heads could be used and grey water recycled in the garden.

Figure 10.1: Linking water and livelihood security (Household use, agriculture, economic development, job opportunities)

Where relevant, the management of water could also be addressed at the local level. Some villages have access to small dams; the timing of releases could be adapted to be more flexible in response to current conditions and water could be allocated for water efficient, rather than water intensive, activities.

Although it is not discussed here, changes in flood impacts are also important to consider. If the intensity and frequency of floods increases, measures are needed to reduce exposure to this risk and improve ability to cope. In some places this might involve better zoning so that infrastructure is less likely to be damaged. In other places it might involve adapting infrastructure such as roads and bridges to be more resilient to flood damage. It may also require improved early warning systems so that people and their assets can be moved out of flood zones in time.

Some of these adaptation responses can be implemented by households, whereas some are likely to need support from the municipality or local organizations. The role of River Basin Organisations (RBOs) should also be explored. Although RBOs have the advantage of being able to look at the river basin more holistically, they can also support activities that will have a benefit for people at the local level.

RBOs provide a unique opportunity for stakeholder engagement. Their mandate is usually to involve a wide range of stakeholders from within the basin. Because of this they should be able to provide a place for the voice of the most vulnerable groups to be heard alongside those of experts. This is important in order to ensure that intervention at a larger scale seeks to address the needs of the most vulnerable and their concerns related to water, as they may be quite different to planners focusing on an entire district.

Building on from this, RBOs could help to support equity in water allocation. An assessment would be needed of how changes in rainfall impacts would affect water availability and access for most vulnerable groups. Often national development needs might be prioritized, but it is important that those without a voice are not rendered worse-off by the impacts from a changing climate.

RBOs could also be used as vehicles for education on how climate is changing and what the potential impacts could be. Through this process, climate scenarios could be explained in local language and potential adaptation responses could be explored. Information on what resources exist could also be provided through this forum.

4. Limpopo Basin case study: Sekhukhune district, South Africa

Sekhukhune district in Limpopo Province, South Africa (Figure 10.2) is used here as a case study to explore what various actors are doing to address key development needs and explore how they relate to climate. To better understand the dynamic nature of vulnerability and people's coping and adaptation strategies, the research explored what stressors people think are most pressing, what climate impacts are being felt, and how people are trying to deal with these challenges. People experience and respond to stressors on many scales; in this research, particular focus was placed on the village (local) and municipal (district) scale to understand how actors' perceptions and activities compare.

Sekhukhune lies in the summer rainfall region of South Africa, receiving a mean annual rainfall of between 500 and 800 millimetres (DWAF, 2005). The district of Greater Sekhukhune cov-ers an area of 13,264 square kilometres and has a population of about 1,125,000 (Aird and Archer, 2004; DWAF, 2005). There is a high level of poverty, with 84% of people defined as poor, i.e. receiving an income of less than R1,500 (South African rands) per household per month, and 66% defined as very poor, i.e. having less than R550 per month (DWAF, 2005). Unemployment in Sekhukhune currently stands at 69%, much higher than the provincial average of 49% (Greater Sekhukhune District Municipality, 2005). This causes many people to migrate to other parts of the country to find work.

The main economic activities in Sekhukhune are mining and irrigated agriculture. Platinum, chrome, gold and palladium mines are situated in the eastern part of the district, around the Leolo Mountains (DWAF, 2005). There are commercial irrigated farms near Groblersdal and Marble Hall in the south west and Zebediela in the north (DWAF, 2005); however, only 30% of the land area of the district is under commercial farming (Greater Sekhukhune District Municipality, 2005). Growth is hampered by scarcity of water in the agricultural and mining sectors, as well as by the uncertain status of land ownership, with 75% of the land in Sekhukhune being under land claims (Greater Sekhukhune District Municipality, 2005).

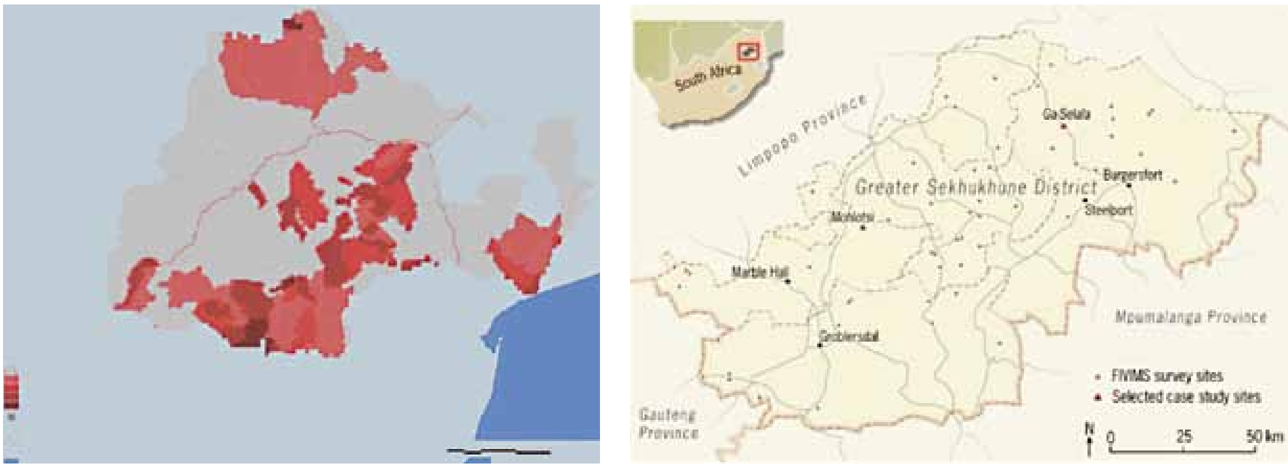


Figure 10.2: (Left) Hydrological, political, and population characteristics of the Limpopo Basin. (Right) Map of Sekhukhune District, Limpopo Province and research villages, Mohlotsi and Ga-Selala (Sources: (L) Louw and Gichuki, 2003 in Earle et al, 2006; (R) GridArendal)

Ga-Selala (village)	Greater Tubatse Municipality
Domestic supply limited	Basic services need to be addressed
Irrigation is not feasible but desired	De Hoop dam will solve problems
Crops and home gardens suffer without access to water	Industry/mining/agriculture competing over water resources

Figure 10.3: Key concerns around water in Tubatse

5. Methodology

Previous work and experience in the field had suggested that the focus on climate change might exclude other factors contributing to vulnerability to current climate variability. Rather, people are impacted by climate variability, but response to climate is not necessarily intentional as people respond to a range of stresses of which climate forms only part of the problem. Therefore, field based research in South Africa sought to explore how local stakeholders perceived stresses and responded to these stresses. These perceptions were related back to climate, rather than allowing a focus on climate to dominate the investigations.

The research was framed from a combination of a vulnerability and livelihoods perspective and was integrated with an institutional analysis approach. Fieldwork was undertaken in two villages in Sekhukhune District, viz. Mohlotsi and Ga-Selala. The former is on the wetter eastern side of the district close to the commercial farming area and the latter is on the drier eastern side of the district where mining activities dominate.

The qualitative approach included semi-structured interviews that were under-taken with 20 households, followed by a number of focus groups, held separately with men and women who tend to have different responses linked to their cultural realities. Semi-structured interviews were also con-ducted with officials from the local and district municipalities. In two follow-up visits, the initial analysis was fedback to and discussed with the participants, highlighting differences in perceptions and the need for more integrated research to understand the interactions between various stressors and to prioritize actions in view of differential decision-making power and responsibilities.

The quantitative methods included the application of Stated Preference (SP) and Discrete Choice Analysis (DCA) techniques that were used to assess individuals' reactions to a hypothetical situation involving a specified combination of stresses, in terms of the coping and/or adaptation strategies they would engage. This survey was undertaken with 100 village respondents. The situation and response options were based on their perspectives gained through the use of the qualitative methods. This approach provided a range of contextual and quantitative data on response options.

An important characteristic of this work was the assessment of local vulnerability as perceived by villagers as well as by local and district level government officials and the various response activities engaged in by these different groups. This enabled an interesting comparison to see if vulnerability and consequent responses, at different scales, were predominantly complementary or conflicting.

6. Findings

There were a number of stressors perceived to be concerning at both the village and municipal levels. Poverty and food insecurity, as well as water stress emerged as the most concerning stressors at both levels.

At the village level water stress was prioritised in both Mohlotsi and Ga-Selala villages (summarizing table page 199). In Ga-Selala, where there are standpipes, water stress applies to both domestic use and agriculture. In Mohlotsi, where households receive reticulated water, water is still a stress as it limits agricultural production and other economic activities, such as brickmaking. Environmental concerns were mentioned in relation to land quality and rainfall. Erosion was a concern in Mohlotsi, especially after heavy rainfall and this degradation was seen to impact on soil quality.

Water stress was important to municipal officials in terms of bulk domestic supply and provision of water for agriculture. Small and weak markets were recognised as a limitation to development within the district. Community-based projects require alternative support to simply providing start up capital, if they are to be sustainable.

In the follow-up field trips, the key stressors were summarized and presented back to respondents. Table 10.3 shows the concerns linked to water in the Tubatse municipality as expressed at both the village and municipal level.

In the focus group, the Ga-Selala villagers were asked whether the points made were represented fairly. In relation to the concerns around water they said, 'Yes, those are the points. People are frustrated that things aren't happening quickly enough. The municipality isn't responding to our needs. Too many boreholes around the village are not working. There are four hand pumps that are all broken and the municipality doesn't do anything to fix them.' And in responding to concerns around climate they said, 'The last good rainfall was in 1995, even though it should be flooding here now. It looked promising this year so we planted. But there has been no rain, so there will be no harvest.'

The municipal officials' response to the findings was relatively supportive. At the municipal level they wanted to add additional information. For example, they thought sanitation should be added as something that needed to be addressed in tandem with water access. They agreed that they were not integrating climate change information into their activities, but acknowledged the need to address it. They also acknowledged that grants, food parcels and irrigation schemes were not sufficient to deal with the problem of food insecurity in the area, although, other solutions were not discussed.

It was clear that the impact of water stress was a significant stressor at all levels (village, local municipality and district). Water resources are directly impacted by current climate variability and it is expected that climate change could impact on water resources significantly in the future (Schulze and Tyson, 1997; Arnell, 1999; Schulze, 2005; de Wit and Stankiewicz, 2006).

Future expected climate

Downscaled climate change scenarios available from the Climate Systems Analysis Group at the University of Cape Town provide an indication of expected future climate, based on station data from Lydenburg. This data suggest that by 2045, more raindays can be expected in some of the summer rainfall months (between October and January), with some of these months seeing an increase in intensity with more rain

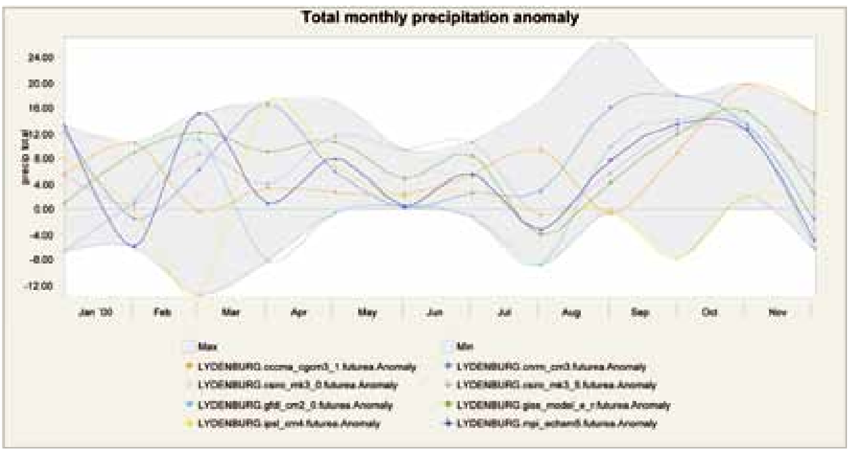


Figure 10.4: Climate change scenarios for Sekhukhune district (left: Climate change explorer - www.csag.uct.ac.za | www.weAdapt.org)

2045
October & January: more raindays
November: increased intensity, increase in monthly rainfall amount & no. of raindays
Length of dry spells reduced
Increasing temperatures

Total precipitation
Probably increase
Change in timing & intensity may impact current supply

Water security
Need to link to run-off and other models to understand secondary and tertiary impacts
Although annual precipitation may increase, security of supply may decrease

falling during each rain event. Along with this an increase in monthly rainfall amount and the number of raindays is expected. It is also likely that the length of dry spells will be reduced.

Climate change scenarios do not all agree on the sign or amount of rainfall change in the region. This makes it difficult to plan adaptation. If it decreases there is likely to be less water available as runoff is greatly affected by reduced precipitation. If it increases, there is a likelihood that the distribution of the rainfall through the season might change and be accompanied by flooding. In addition, the rising temperatures are likely to increase evaporation. Therefore it is not guaranteed that more water will be available even in a scenario with increased precipitation. What is clear is that increases in temperature and changes in the timing and amount of rainfall are going to require current water resource management strategies to be reconsidered. Improving efficiency and reducing demand in the district and provincial water management system are likely to be "no regrets" options, which would appear to be a good strategy in this case.

Future adaptation options

The findings indicated that water stress is a key concern in Sekhukhune and it is clear that water availability, and access to it, are likely to be impacted by climate change. The water sector is therefore a good point of entry for exploring how to adapt to climate change in Limpopo Province. This ties to provincial goals as well, as illustrated by a quote from the former Premier of Limpopo, Mr. Sello Moloto,

"Climatic change is not something we can stop. Limpopo is a province of extremes, swinging between drought and flood. But this new drier future is a whole new thing. "We cannot just sit and wait for it to arrive. The government is proactively and aggressively driving new policies to stretch every drop of water we have as far as possible." (Mail and Guardian, 2006)

Given that water limitations currently restrict district development and impact on the livelihoods and vulnerability of many people, adaptation within this sector links directly to development priorities. Although total precipitation could increase, it is not clear that it will be accompanied by increased availability of water. Increased variability and increased intensity of flooding might result in less water being captured and available for productive and reproductive use.

Reducing current demand would be a good initial step. South Africa is a water-stressed country which has led to exploration of ways to reduce water demand and measures have been taken at a national level to support this, with a move to supply-driven approaches. Activities that help conserve water at the local level, including gutters, rainwater harvesting tanks, stricter planning regulations and a drive to help industry develop new appropriate technologies that are more water efficient, are being explored in Limpopo (Mail and Guardian, 2006). Yet, these ideas were not put forward by local people and so perhaps this emphasises the need to improve communication and skills on these issues so that there can be adaptation by local people that builds on existing activities and introduces new ones where appropriate.

At the broader district and provincial levels, decisions are being made between the prioritisation of water for mining and agriculture. An understanding of current climate variability and future climate change might help inform these decisions, more importantly, however, it is necessary that these discussions occur at the basin level. The province might be focused on economic gains, whereas basin organizations can focus on governance issues and provide support for this. Although approaches initiated by basin organisations might focus on catchments, they are likely to have an impact on households, if implemented appropriately.

If supply is likely to become more variable, non-water intensive activities should be supported through tax incentives or alternative means. Government stakeholders mentioned that tourism is being pursued as an important sector to contribute to the economic development of Sekhukhune. Although luxury tourism has significant water demands, these may be small compared to current activities. If natural vegetation is encouraged to regenerate, then natural climate variability is not an extreme threat; although, if game is introduced, the impact of drought will be felt on rangeland quality as well as on environmental and animal health. While developing the tourism industry might bring increased revenue, the actual jobs created might be limited.

Commercial agriculture, including cultivation of cotton, citrus, grapes and other crops, exists in the south west of the district and is highly dependent on water availability and the timing of rainfall. Therefore adaptation within the agriculture sector needs to explore ways of adapting to potential changes in rainfall patterns and associated water availability. This industry brings money to the district, but is highly water intensive. Most of the farms remain under the ownership of previously privileged white farmers, although there are a growing number owned and managed by black farmers. The large farms provide seasonal employment for many. However, as mentioned by a respondent in Mohlotsi, this seasonal work is erratic as the number of workers needed fluctuates intra- and inter-annually, and those given work varies indiscriminately because few skills are needed. One of the officials involved in water resource management mentioned that, as a district, they were considering reducing the amount of water allocated to commercial agriculture and diverting it for domestic use, so that more villages can receive reticulated water, in places where there are currently standpipes but not yet piped water to peoples' houses.

Mining, an important sector in Sekhukhune, is growing rapidly and with it water demand. Decisions are currently being made about the allocation of water to the mines. Mining has the potential to generate large amounts of revenue and potential employment opportunities in the district. It is critical to assess how this profit is distributed and used and who gets access to jobs. If the province invests the profits back into the local economy, long term benefits can be established such as improving schooling and health systems. If the money is not reinvested then locals perhaps stand to benefit in the short-term, but not in the long term. Although mining generates jobs, interviewees suggested that the jobs do not often go to local applicants. Many go to those with previous mining experience, often those that have been employed by the mining company in mines elsewhere in the country. Local politics are an additional challenge. Ga-Selala members stated that their chief was not favoured by the mining employers, limiting their access to jobs. In addition, the mines were likely to result in higher HIV prevalence rates which have significant social and economic costs. It is therefore important that water allocation employs the precautionary principle to protect the rural poor from adverse effects of (the expansion of) the mining industry, as has been suggested in relation to the sugar industry in the adjacent Inkomati basin (MXA, 2006). At the same time, domestic water demands need to be carefully balanced with other development needs.

Small-scale agriculture is not viable in many parts of Sekhukhune where it is relatively dry. Perhaps increases in precipitation will make agriculture more viable in some areas and allow people to continue agricultural activities that are currently marginal. However, increasing variability might also make certain agricultural practices more vulnerable. Currently, in parts of Sekhukhune, households have plots of rain-fed crops and there are a number of government funded irrigation schemes across the district. In many instances, irrigation projects have failed. Yet, in both villages where in-depth research was conducted, there was the desire to establish new irrigation schemes and farming projects, although the stated preference questionnaire in Ga-Selala indicated that the actual number of people who were interested was relatively low (poultry farming, 17 and communal gardening, 16 out of 92). Constraints were mentioned by villagers about infrastructure and access to water. They also mentioned access to relevant knowledge about farming and marketing as a constraint. The possibility exists of adopting water-saving technologies and continuing to pursue agricultural activities, although the impact on and constraints from regional water supplies need to be considered. It is likely that these decisions will not be driven by the local level, but rather the provincial level. What is clear, however, is that reduced agricultural activities should be supported by alternative livelihood options.

Home gardens were found to be an important livelihood strategy. Many of the households interviewed had a small patch where they appeared to be growing some produce. In Mohlotsi, where houses have piped water, people mentioned that water was too expensive to use for agriculture. Yet some of these households had gardens where some crops were growing, primarily rain-fed. In Ga-Selala, where conditions were drier than in Mohlotsi, there appeared to be many small fenced gardens adjacent to the houses. People said that they were not able to water their home gardens as there was already high stress on the standpipes for domestic water and the added use of this water source for home gardens resulted in the water running dry too frequently. Home gardens are supported as a means to address food security in the Integrated Food and Nutrition Security Programme (Department of Agriculture, 2002), therefore they need to be carefully examined in terms of their vulnerability to climate variability and change.

Many households have developed a wide range of coping and adaptation strategies in response to changing conditions that affect their livelihoods and well-being. Most of these are in direct response to a lack of money and/or food. Even though the climate is highly variable and droughts occur frequently, most people do not perceive it as a direct stressor. Rather, it is the limited amount of available water, affected both by climate and human management, they respond to. This finding supports the assertion that adaptation to climate change is not simply an isolated response to the impacts of climate variability and extremes, but rather a complex set of responses to a range of interacting and dynamic stresses, of which climate is one (e.g. Adger et al., 2005).

Despite increasingly scarce water resources and high uncertainties concerning potential climate change impacts, future regional development relies to a large extent on irrigated agriculture and mining, both of which are highly water-intensive. The rationale behind this strategy needs to be questioned because it is likely to increase future vulnerability to water stress. Exploring alternative development options that are less water-intensive and less sensitive to climate variability could contribute to adapting to climate change. There are also important health concerns associated with the two dominant growth sectors of mining and agriculture. The influx of migrant workers attracted by the opening of new mines and the increasing number of truck drivers passing through the area to transport agricultural produce is expected to greatly increase levels of HIV infection in Sekhukhune. This in turn generates a number of health, social and economic stressors,

Key concerns around water at the village and municipal levels	
Ga-Selala village	Greater Tubatse Municipality
Domestic supply limited	Basic services need to be addressed
Irrigation is not feasible but desired	De Hoop dam will solve problems
Crops and home gardens suffer without access to water	Industry/mining/agriculture competing over water resources

Perceived strategies to respond to water stress		
Mohlotsi village	Ga-Selala village	Municipal + district government
Challenging climate conditions / water scarcity		
Irrigation systems	Transition to less agriculturally based livelihoods	Increase dam capacity to capture more water
Drought resistant crop varieties		Build new dams

Major Findings – Summary

Need for adaptive strategies (linking water and livelihoods)	• Access to water can impact livelihood security - Directly à agriculture and livestock, drinking and domestic use - Indirectly à mining, food prices
	• Yet, water decisions made - Around key district/provincial economic activities - Without considering impact of climate change - Often without exploring the impact on poverty
Potential options for adapting to climate change in Sekhukhune	• Local projects - Efficient irrigation, conservation tillage - Rainwater harvesting - Small business development
	• Integrated in municipal and district planning - Supporting non-agricultural livelihood activities - Reassess infrastructure standards
	• Support from national level - Provisions for climate variability in water management plans - Policies addressing allocation and equity
Adaptation to multiple stresses	• Acknowledge differing perceptions - Not everyone sees climate as most important - Focus on key development stressors and links to climate
	• Target different levels - Recognise constraints & opportunities Give a voice to those most vulnerable they have responded before and need to be consulted about future adaptation
	• Integrate activities across sectors - Livelihoods span across sectors - Climate change adaptation an opportunity to do this

likely to further increase local vulnerability. Mechanisms for combating these negative impacts will need to be developed and implemented, including continued public health education and forms of social and economic empowerment, especially for women.

It is clear that there are different scales and actions involved in responding to changing water stress. Adaptation to climate change in Sekhukhune will therefore be best addressed through an integrated approach that focuses on bringing a range of stakeholders together to explore how best to adapt to changing water availability. Although it has been recognised that climate change is impacting on water resources and associated development, adaptation planning with explicit recognition of the nature of climate change, has not been undertaken. This is an urgent priority and climate adaptation policy is needed to support this goal.

7. Conclusion

South Africa's National Water Act is considered one of the most comprehensive examples of water legislation in the world, based on equitable water allocation through an integrated approach which addresses past social injustices as well as promoting economic growth, environmental integrity and poverty reduction (Hope, 2006). In February 2001, legislation was adopted that set a 6-kilolitre free minimum quantity of potable water for per household per month (Gowlland-Gualtieri, 2007). Despite this, much of the country, especially in rural areas, remains under- or un-served with the benefits of the Free Basic Water Policy failing to reach or reflect the needs of these communities (Hope, 2006). If climate change places additional strain on water resources, this goal will be even more difficult to meet.

The case study of Sekhukhune district, Limpopo Province, South Africa, indicated that water scarcity and limited economic opportunities are two major constraints to development at both the village and district scales that undermine capacity to adapt to change. Therefore, if one is concerned with adaptation to climate change, it would help to understand how to reduce vulnerability to key constraints and how these relate to climate stress. It was possible to reach these conclusions because a multiple stress approach was taken in the research that was conducted. Even though the starting point was to establish the role of climate, water and health stress in shaping livelihood activities and decisions, and hence their vulnerability to these stresses, the findings illustrated that the response to stress is governed by peoples' perceptions of key stressors which requires responses to be viewed through the lens of local stakeholders. In this case many decisions were influenced by the primary stresses of water scarcity and limited economic activities. If adaptation to climate variability and change is a concern, it is sensible to recognize how the stress of water scarcity and economic activities will be impacted upon by climate variability in order to support the key stresses of the community. The policy implications of this suggest the need to depart from hegemonic sectoral approaches and focus on integrated responses to support local adaptation, because multiple stresses challenging the villages are interrelated and often reinforce oneanother.

It is important to take a cross-sector and cross-scalar approach, even when trying to support vulnerable livelihoods. Focusing on small projects at the village level might not be the best approach to supporting adaptation if it is expected that climate change will be widespread and therefore impact large areas covering multiple villages where one-off projects to cope with climate change will not be enough. Approaches to supporting adaptation to climate change could therefore benefit from engaging with institutions at the municipal, district and basin levels. This research highlighted the need for an improved understanding of issues related to governance and institutions, such as the relations between traditional and elected leaders and the need for participation in government decisions of direct consequence to local people. This lesson can be applied more broadly, as much research on adaptation to climate change has tended to focus on local projects or national priorities. Yet, as this research shows, much implementation of policy and support for vulnerable groups happens at the local level. Understanding local governance issues is therefore necessary to facilitate adaptation action and success. This is an area that requires increased research in order to better understand how climate change adaptation might be supported through increasing local government capacity to plan with climate variability and change in mind.

Departing from a sectoral approach requires improved and increased communication between government, local communities and other organizations, to facilitate the integration of strategies being implemented at different scales and better align expectations. RBOs are particularly well suited for this role, which should be supported as a matter of urgency. This response should include improving access to climate information, if it is to become integrated into response strategies. It should also recognize that local adaptation is not about working with individuals at the household level only. It is about recognizing that marginal households are part of a village, part of a municipality and part of a river basin. It is therefore urgent to pursue an approach that integrates across scales and sectors when evaluating adaptation to climate change to contribute to supporting larger development needs.

References

Africa Commission (2008). Climate change. http://www.africacommission.um.dk/NR/rdonlyres/451E2E5B-E459-4B5F-A4F8-318783D5AF3B/0/PDF080411ACdiscussionpaperonClimatechange.pdf [Accessed July 2008]

Aird, R. and Archer, E., (2004). Sekhukhune Background Document. FIVIMS-ZA report, Kayamandi Development Services & Climate Systems Analysis Group, University of Cape Town. 42pp.

Bohle, H.G., Downing, T.E. and Watts, M.J. (1994). Climate Change and Social Vulnerability: Toward a sociology and geography of food insecurity. Global Environmental Change, 4 (11), 37-48.

Boko, M. et al. (2007): Africa, climate change - impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry et al (eds). Cambridge University Press, Cambridge.

Department of Minerals and Energy. Social and labour plan guidelines for the mining and production industries. http://www.dme.gov.za/minerals/documents.stm. [Accessed 18 May 2007].

Downing, T.E., Aerts, J., Soussan, J., Barthelemy, O., Bharwani, S., Ionescu, C., Hinkel, J., Klein, R.J.T., Mata, L.J., Martin, N., Moss, S., Purkey, D. and Ziervogel, G. (2006). Integrating social vulnerability into water management. SEI Working Paper and Newater Working Paper No. 4. Oxford: Stockholm Environment Institute.

Department of Water Affairs and Forestry (2005). Water Services Planning Reference Framework, Sekhukhune District Municipality. DWAF, inviromap and GPM Consultants, Pretoria, 124pp.

Earle, A.; Goldin, J.; Machiridza, R.; Malzbender, D.; Manzungu, E.; Mpho, T. (2006). Indigenous and institutional profile: Limpopo River Basin. Colombo, Sri Lanka: International Water Management Institute. 65p. (IWMI Working Paper 112)

Franklin, S. (2004). Towards a narrative theory of climate change vulnerability. Stockholm Environment Institute.

Füssel, H.-M. and Klein, R.J.T., (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. Climatic Change, 75. 3.

Gowlland-Gualtieri, A. (2007). South Africa's water law and policy framework-Implication for the right to water. International Environmental Law Research Centre (IELRC) working paper. Available from: http://www.ielrc.org/content/w0703.pdf [Accessed 26 July, 2008]

Greater Sekhukhune District Municipality, (2005). 2004/2005 IDP Review. Greater Sekhukhune District Municipality, http://www.sekhukhune.gov.za/legs_docs/plans/_PDF/Sekhukhune_IDP.pdf (accessed 22 May 2006), 149pp.

Hope, R.A. (2006) Evaluating water policy scenarios against the priorities of the rural poor. World Development, 34(1): 167-179.

Ionescu, C., Klein, R.J.T, Hinkel, J., Kavi Kumar, K.S. and Klein, R. (2005). Towards a Formal Framework of Vulnerability to Climate Change. NeWater Working Paper 1, Potsdam Institute for Climate Impacts Research, Potsdam, Germany, ii+20pp.

IPCC (2007). Kundzewicz, Z.W. et al., (2007) Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M.L. et al. (Eds), Cambridge: Cambridge University Press, 173-210.

International Water Management Institute (2007). Water: Key for adapting to climate change. http://www.iwmi.cgiar.org/Publications/Other/PDF/ClimateChangeFlyer.pdf

Kelly, P.M. and Adger, W.N. (2000). Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation. Climatic Change, 47 (4), 325-352.

O'Brien, K., Eriksen, S., Schjolden, A. and Nygaard, L. (2004). What's in a word?: Conflicting Interpretations of Vulnerability in Climate Change Research. CICERO Working Paper 2004:04, Centre for International Climate and Environmental Research, Oslo University, Oslo, Norway.

OneWorld (2008). Feasibility Report. Regional Climate Change Programme: Southern Africa. For Department for International Development.

Reid, P. and Vogel, C. (2006). Living and responding to multiple stressors in South Africa—Glimpses from KwaZulu-Natal. Global Environmental Change 16 (2), 195-206.

Segnestam, L. (2004). Poverty and Vulnerability to Environmental Stress: Working with Multiple Dimensions of Poverty. SEI Briefing Note. Oxford: Stockholm Environment Institute. 3pp.

Sperling, F. & A. Bouzaher (2008). Climate change adaptation in the sub-Saharan Africa region. Environment Matters, World Bank, Washington.

Turner, B., Kasperson, R., Matson, P., McCarthy, J., Corell, R., Christensen, L., Eckley, N., Kasperson, J., Luers, A., Martello, M., Polsky, C., Pulsipher, A. and Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. PNAS. 100. 14. 8074-8079.

UNDP (2007). Human Development Report 2007/2008—Fighting climate change: human solidarity in a divided world. Available from http://hdr.undp.org/en/media/hdr_20072008_en_complete.pdf [Accessed 24 July, 2008]

Wisner, B., Blaikie, P., Cannon, T. and Davis, I. (2004). At Risk: Natural Hazards, People's Vulnerabiity and Disasters. Second Edition, Routledge, London.

WRI (2007). Weathering the storm – options for framing adaptation and development (by H. MacGray, A. Hammill & R. Bradley). World Resources Institute, Washington DC.

Ziervogel, G. and Calder, R. (2003). Climate variability and rural livelihoods: assessing the impact of seasonal climate forecasts. Area, 35, 403–417.

Ziervogel, G. and Taylor, A. (2008). Feeling Stressed: Integrating Climate Adaptation with Other Priorities in South Africa. Environment,. 50, 2. 32-41.

Ziervogel, G., Taylor, A., Thomalla, T., Takama, T. and Quinn, C. (2006). Adapting to climate, water and health stresses: Insights from Sekhukhune, South Africa. Stockholm Environment Institute. Stockholm.

Chapter 11

Nile Basin Initiative

An overview of Institutional Mechanisms for Mitigation and Adaptation of Climate Change

By Audace Ndayizeye, Executive Director and T. Waako. NBI Nile Basin Initiative Secretariat.

Contents

1. Introduction

Climate change is defined as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. (UNFCCC, article 1).

Human activities, also referred to as anthropogenic factors, contribute to changes in the environment and influence climate. In some cases the chain of causality is direct and clear (e.g., the effects of irrigation on temperature and humidity), while in others it is less clear. Various hypotheses for human-induced climate change have been debated in many fora for many years, though it is important to note that the scientific debate has moved on from uncertainty, and there is now, general scientific consensus that human activity is beyond reasonable doubt the main explanation for the current rapid changes in the world's climate. Consequently in politics the debate has largely shifted onto ways to reduce human impact and adapt to change that is already „in the system".

The biggest factor of present concern is the increase in CO2 levels due to emissions from fossil fuel combustion, followed by aerosols (particulate matter in the atmosphere), which exert a cooling effect, and cement manufacture. Other factors including land use, ozone depletion, animal agriculture and deforestation, also affect climate.

The global trends of climate change have attracted debate at various levels of governance. The climate changes have impacted negatively on various sectors of society. Africa, especially sub-Saharan Africa, is one of the most affected areas. In recent years Africa has experienced an increased frequency in extreme weather events followed by the related calamities like famine and flood, including loss of lives. It is reported that climate related issues can reduce the per capita economic growth in the order of 1 – 2%. Africa is therefore experiencing severe impacts due to climate change and climate variability. Africa has the lowest capacity to adapt to the projected climate change. It can therefore be concluded that Africa is the most vulnerable continent on the globe. Lack of structural capacity to regulate the effects of extreme weather conditions has contributed to the adverse effects climate change has had on Africa. The water storage capacity necessary for mitigation of drought effects and attenuation of floods is generally low compared to the rest of the world. Major flood control hydraulic structures include the major dams on the Nile; namely, the Roseires Dam and Sennar Dam in Sudan; the Aswan High Dam in Egypt; and the Owen Falls Dam in Uganda. The Roseires and Sennar Dams are situated on the Blue Nile and were constructed in the early 1900s, pricipally for irrigation. The Owen Falls Dam commissioned in 1954 mainly for hydroelectric power supply, is situated on the White Nile at the mouth of Lake Victoria. The High Aswan Dam is more recent, having been commissioned in 1970 and constructed mainly as a multi-purpose facility to control flooding, supply power and water for agriculture. On the other hand, the capacity for soft tools like early warning systems for mitigation measures is also under-developed in Africa. There is a lack of long period and good quality data, as well as models to assess climate change and climate variability impacts in the region so that appropriate adaptive actions can be undertaken to mitigate climate change.

There are, however, traditional practices that were used for adaptability and mitigation of the effects of extreme weather scenarios; including storage of food in preparation for famine that usually follows droughts. In general, climate issues are interwoven in many elements of our livelihoods and need deliberate and multi pronged efforts to avert their adverse effects.

This paper presents the approach for institutional mechanisms for mitigation and adaptation of climate change.

2. Sustainable Development and Mitigation

Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but in the indefinite future. The term was used by the Brundtland Commission which coined what has become the most often-quoted definition of sustainable development as development that „meets the needs of the present without compromising the ability of future generations to meet their own needs".

The field of sustainable development can be conceptually divided into three constituent parts: Environmental sustainability, economic sustainability and sociopolitical sustainability.

Holistic approach/integrated approach

Sustainable development does not focus solely on environmental issues. The United Nations 2005 World Summit Outcome Document refers to the „interdependent and mutually reinforcing pillars" of sustainable development as economic development, social development and environmental protection (fig. 11.1).

Economic Sustainability: Agenda 21 clearly identified information, integration, and participation as key building blocks to help countries achieve development that recognizes these interdependent pillars. It emphasizes that in sustainable development everyone is a user and provider of information. It stresses the need to change from old sector-centred ways of doing business to new approaches that involve cross-sectoral co-ordination and the integration of environmental and social concerns into all development processes. Furthermore, Agenda 21 emphasizes that broad public participation in decision making is a fundamental pre-requisite for achieving sustainable development.

Environmental sustainability is the process of making sure current processes of interaction with the environment are pursued with the idea of keeping the environment as pristine as possible based on ideal-seeking behavior.

Sustainability requires that human activity only uses nature's resources at a rate at which they can be replenished naturally. Inherently the concept of sustainable development is intertwined with the concept of carrying capacity. Theoretically, the long-term result of environmental degradation is the inability to sustain human life. Such degradation on a global scale could imply extinction for humanity.

The conservation of the natural resources needs to be balanced with development that does not significantly affect the natural resource base. Development options that minimize loss of the natural resources need to be explored.

The dilemma under the institutional arrangements however, is how an acceptable balance by all sectors can be defined. There are challenges of knowing the needs of the future generations, especially considering the technological innovations and other change factors. Sustainable development is also affected by the population growth. It is expected that natural resources have a limit in terms of carrying capacity, beyond which the resources are stressed and difficult to manage in a sustainable manner.

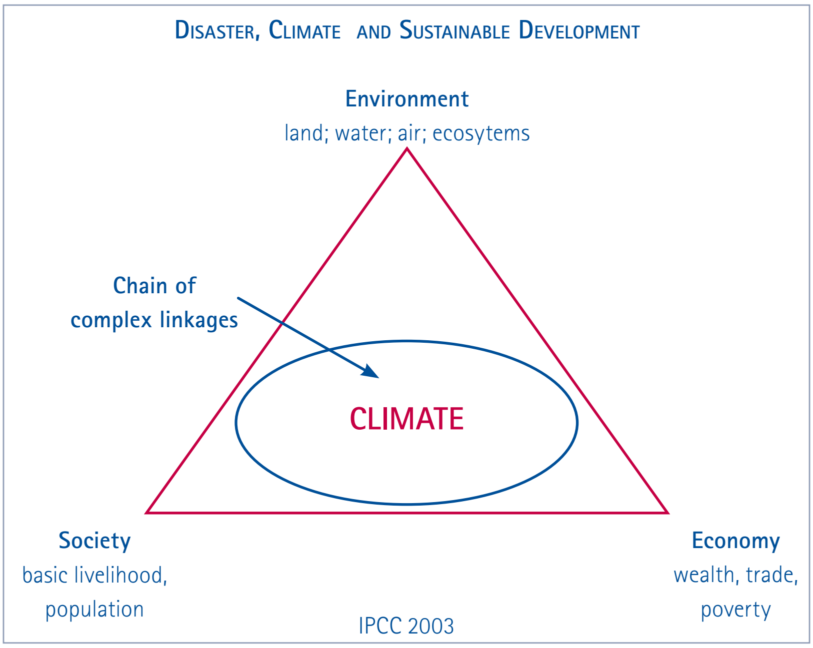


Figure 11.1: Pillars for sustainable development.

3. Institutional Mechanisms for Mitigation and Adaptation

Institutional arrangements and responsiveness have been growing in light of the increasing world concern over climate change as both witnessed in various trends and confirmed by scientists. Institutional mechanisms are important in determining the quality of governance of the climate change matters at all levels. These mechanisms translate the strategies for climate change management into effective mitigation measures and adaptive practices, and, as such, institutional mechanisms are key drivers to climate change mitigation. The institutional architecture to address climate change issues is invariably diverse and can be examined based on the hierarchical orientation or their spatial scales. Institutional mechanisms provide tools to address variability and extremes not restricted to infrastructure. These institutional mechanisms are often cheaper, more effective and can complement infrastructure.

The institutional mechanisms can be assessed based on their vertical and horizontal orientations. On the horizontal orientation there is strong emphasis of coordination and collaboration among stakeholders on the same level of hierarchy. This could be among sectors at the global, regional, national, or community levels. Effective links and liaisons among stakeholders in areas like information sharing is key and useful at all levels of climate change as it facilitates prudent coordination of CC activities and harnesses synergies.

3.1 Global scale

On the global scale a number of initiatives have been instituted to address climate change issues. These initiatives fall under different frameworks of the United Nations and they include, UNEP, WMO, IPCC, UNFCCC and its subsidiary bodies.

Traditionally issues of climate variability are covered primarily under the WMO and UNEP. Established in 1950, the WMO became the specialized agency of the United Nations for meteorology (weather and climate), operational hydrology and related geophysical sciences. The Organization has established Global Earth Observation System (GEOS) and the Global Climate Observation System as part of the tools for monitoring climate.

The United Nations Environment Programme (UNEP) is the United Nations designated organ for addressing environmental issues at the global and regional level. Its mandate is to coordinate the development of environmental policy consensus by keeping the global environment under review and bringing emerging issues to the attention of governments and the international community for action.

Realizing the need to address climate change, the WMO and UNEP established in 1998 the Intergovernmental Panel on Climate Change (IPCC) as a scientific body tasked with evaluation of the risk of climate change caused by human activity.

The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation.

The IPCC does not carry out research, nor does it monitor climate or related phenomena. A main activity of the IPCC is publishing special reports on topics relevant to the implementation of the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty that acknowledges the possibility of harmful climate change; implementation of the UNFCCC led eventually to the Kyoto Protocol. The IPCC bases its assessment mainly on peer reviewed and published scientific literature. The IPCC is only open to member states of the WMO and UNEP. IPCC reports are widely cited in almost any debate related to climate change.

The climate change issues touch in a random manner every entity in society, and as such holistic approaches are important in formulating mitigation measures and formation of viable adaptive practices. Partnerships have been formed in varying scales to concertedly respond to climate change issues. Global Development Partners have dedicated resources to understand, ameliorate victims in disaster hit areas and formulate strategies for mitigation as necessary. These include the multilateral partners like the UN, World Bank; civil society, private sector and research organizations like IWMI.

Resounding calls on the need for world efforts to address climate change issues have been made in many high level international fora. The declaration from the Commonwealth Heads of Government Meeting held in Kampala in November 2007 emphasized climate change as one of the major challenges of the world today. Conference of the Parties 13 (COP 13) in Bali recommended the strengthening of institutional capacity in addressing the climate change issues.

3.2 Regional scale

Regional interventions towards climate change mitigations and adaptations, just as global scale interventions, are included in the general framework of the United Nations System.

There are three major climate centres in Africa. These are ACMAD in Niamey, ICPAC in Nairobi and DMCH in Harare for the SADC region. These regional centres are important as the scales of impacts of climate change are commonly more visible at the regional level. This has prompted regional organizations like River Basin organizations, Regional Economical Communities to give attention to climate change issues on a regional scale. For example Elnino was experienced in the East African region in 1997/98 leading to flooding and damage to physical infrastructure, and affected the national economies in the East African. Settlements were submerged, and the event was followed by an outbreak of water-borne diseases adding an extra strain on the consequences. Similarly the drought spell of 2004/2005 caused the water levels in East Africa to reach record lows leading to power shortages as most countries depend largely on the hydropower schemes. Consequently, the economies of the eastern African countries were significantly affected. This event also caused crop failure in many parts and, hence, famine in many parts of the region.

Similar to the global arena, the regional arena has also seen the emergence of strategic partnerships geared towards addressing climate change issues. The recently concluded African Union (AU) conference in Sharm El Sheik, Egypt dealt with the theme of water and sanitation. The issues of climate change featured prominently as one of the major challenges for Africa. Other Ministerial Councils have also echoed concerns on climate change, principal among these are the African Ministerial Council on Water; the African Ministerial Council on Environment; and the African Ministerial Council on Energy. All these have in one way or the other been greatly affected in their delivery of services by climate change related impacts.

Major regional bodies like Regional Economic Communities and River Basin Organizations in Africa have a key role to play in addressing the challenge because of the regional oversight and national anchorage. For example the East African Community through the Lake Victoria Basin Commission was proactive in conducting a study on the falling water levels in the region and so inform the partner states on the strategic measures required.

3.3 Addressing climate change issues on the national and community levels

Governance of climate change issues at the national level plays a key role in the implementation of regional and global strategies, mitigation of impacts and adaptation of practices. The focal points for climate change issues are the institutions in charge of meteorology. These institutions are also the focal point for implementation of global conventions and protocols like the UNFCCC, Kyoto protocol etc. The issue of climate change has gained significant recognition since it has proved as having a bearing on the national plans. Climate change and climate variability matters were previously responded to as emergency cases. Following the high frequencies of such occurrences experienced in recent years they are being assimilated in the planning processes of the relevant sectors of national governments.

At the community level, land use practices are applied which affect the micro climate. It is an important spatial scale of consideration, with the management guided by the policy regime at national level. The common challenge in Africa is the apparent lack of information at community level. The history of civil instability in many of the sub-Saharan countries has contributed to inhibition to growth in many development ventures including loss of opportunities for capacity development in climate change management and other critical areas. There is a need to develop a strategy for capacity enhancement in management at the community level.

The challenge of capacity in its various forms is evident and exacerbates the vulnerability of Africa to climate change. Besides the disparities at regional, national and community levels, there is general lack in human capacity to adequately articulate and engage in devising solutions to climate change in most of the African countries. The situation is compounded by a lack of institutions to effectively manage and control the climate related activities. The systems for information collection are not available in many parts of the continent. Early warning systems are not available rendering the region prone to climate change impacts. There is a need to develop a strategy for capacity enhancement in management at the all levels.

Key players need to be brought on-board to influence the action at the national level. Legislators and policy makers are some of the key players that can support the process of formulating and instituting robust strategies to climate change issues.

While the changing climate is appreciated in the national plans, there is a need to go further and devise monitoring programs of the interventions and undertake appropriate reviews to improve the interventions.

4. Climate Change Issues: The NBI Context

The Nile Basin is a natural surface drainage system of strategic importance on the continent of Africa. Covering a basin area accounting for 10% of the area of Africa, its effective management and control is of prime strategic importance in the management of the continent's water resources. The contemporary management of the basin, Nile Basin Initiative (NBI), is deemed to bring many returns and rewards to the riparian countries and formidable lessons for the neighboring states – if not the entire continent. This hydrological unit is unique with diverse physical, cultural and socio-economic backgrounds. The Nile Basin Initiative is a transition institution which was established in 1999, pending the establishment of a permanent river basin organization. The NBI is guided by a shared vision which states "To achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin Water resources". The NBI was formed to spearhead the implementation of the development track of the Nile Basin countries. The NBI is aimed at cooperative development of the basin based on the water resources, and has been engaged in formulating and implementing development projects since its formation. At its inception, the region was characterized by many economic, human and societal challenges. Appalling statistical figures in terms of international development, reflecting poverty, lack of investment and environment degradation were common in the area. At that time the pressing and immediate needs of the Nile Basin countries did not warrant prioritizing directly the climate change issues; as such they were not given prominence in the initial formulation of the first generations of projects. However mitigation measures were intertwined in the activities in myriad forms. The Shared Vision Program Projects have built capacity for mitigation of climate change through training, demonstrations and micro-grant projects. Further, frameworks under SVP and Subsidiary Action Programs (SAPs) and small scale investments under the SAPs are aligned to buffer effects of climate change. Throughout the implementation period and of course in the last decade the issues of climate change have taken centre stage in the development initiatives. The NBI has indeed taken steps towards addressing the basin climate change issues in its programs. A concept note aimed at developing a project that will address climate change impacts and adaptation in the Nile basin has been developed to pave way for development of a full proposal for a project on climate change.

Through implementation of the first generation of activities, and the gains through the capacity, trust and confidence building ,the Nile Basin countries are moving ever more towards identifying and preparing joint development and investment projects. This evolution will lead to private and loan based investments, joint infrastructure development in the areas of power, agriculture and water access for the over 300 million citizens of the Nile basin countries. The Nile Basin Initiative fully recognizes the vulnerability of the region to climate change impacts and the need to adapt and mitigate the impacts. Research efforts on the subject of climate change in the basin have been based on global circulation models which have resulted in high level of uncertainties due to their generalities.

The Nile Basin Initiative has undertaken some activities directly or indirectly aimed at addressing climate change issues;

- The Eastern Nile Subsidiary Action Program has developed a Flood Protection and Early Warning System for the eastern Nile sub region.
- The Applied Training Project of the Shared Vision Program has engaged with top level research institutions – the University of Bergen – and currently supports students undertaking research on climate change in the context of the Nile. Other project-by-project assessments are also underway, particularly focused on investment projects.

Furthermore, and in the context of their obligations vis-a--vis the UNFCCC, riparian countries are undertaking vulnerability assessments at a national level either through the preparation of NAPAs or through their national communications. At a bilateral level, several Nile development partners are also supporting climate risk management and adaptation within specific countries (e.g. UN in Egypt, DFID in Ethiopia ...)

The overall objective of the project is to climate buffer NBI's development projects and addresses climate risks management and adaptation through cooperative action at a basin scale. At the end of the project, there will be enhanced understanding of the climate change on the Nile basin's bio-physical system. The risks related to climate change within the investment and development projects will be mitigated or at least the effect lessened. Adaptive capacity at the level of the basin and individual riparian countries will be enhanced. And of course the decision making on Nile issues will be able to integrate climate change parameters.

Two strategic approaches will be considered. One is to consider climate change issues at the preparatory stages of the projects. Secondly, is to prepare a project at basin-wide scale to ensure cohesion among riparian countries and cost effectiveness of adaptation measures. The preferred initiative is to focus at the basin scale, although the information generated through this process may support individual project level management of climate issues. In order to achieve this, it is proposed to proceed in a phased approach; this should enable maximum flexibility so that the scope, budget and partnerships for each phase are determined based on the outputs of the previous one. The global circulation models will be downscaled to regional circulation models. Hitherto not much research aimed at downscaling GCMs has been undertaken in the Nile region. Other tasks will include scenario development, vulnerability assessment and emerging opportunities.

The policy dialogue will be engaged as of the beginning of this initiative, to ensure policy makers understand what it can deliver and how it may affect their decisions and the current state of affairs. This will inform the identification of policy options with decision makers, in terms of adaptation, basin management, its development and investments that may be required to engage in an intentional manner to curb climate change impacts. Technical adaptation measures, such as the establishment of an integrated early warning system linking the Nile countries, investments in vegetation cover to stabilize stream flows, etc… will also be identified and implemented to the maximum extent possible.

Key guiding principles in the formulation and implementation of this initiative will be leveling of the playing field, creativity, and flexibility. Levelling the playing field is in line with principles of development. The initiative will adopt a differentiated approach to capacity development by focusing on those countries with the highest needs. This will be undertaken through capacity assessments based on a scorecard covering institutional, technical, material and individual capacities available and weighted against the vulnerability and preparedness of the country to cope with climate change.

Creativity and innovativeness in addressing climate change issues. While climate change is seemingly always referred to as a risk, it is proposed to also identify the sort of opportunities that it brings to speed up cooperation, increase cohesion at the basin scale and identify locations for furthering the reform processes engaged through the NBI.

Flexibility in approach of implementation is desirable. Given the complex and diverse nature of NBI activities, careful thought needs to be given to the implementation arrangements of the proposed project. Of particular importance are the DSS development process and the normative/regulatory functions of permanent basin organization.

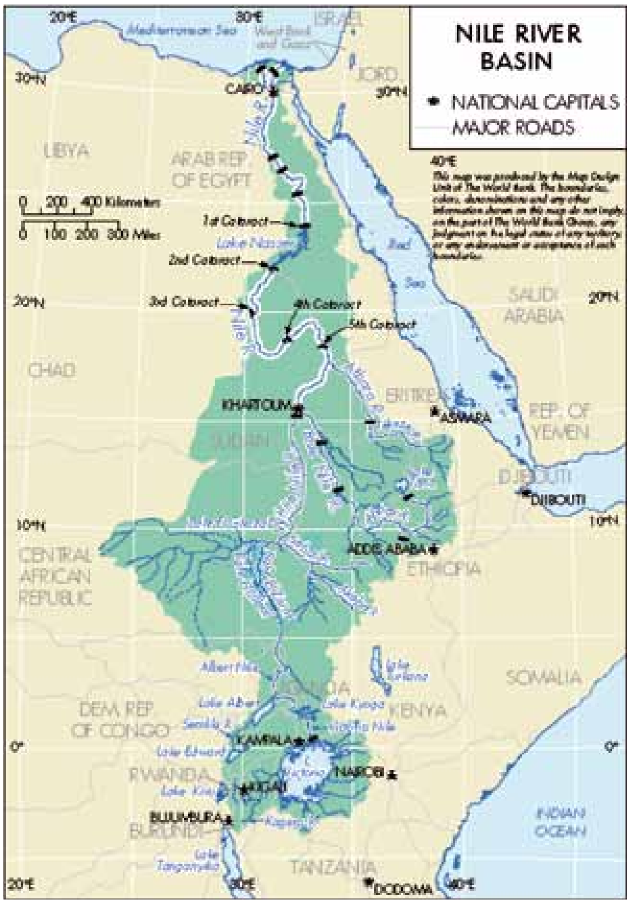


Figure 11.2: Nile River Basin

5. Recommendations and Thoughts

In developing institutional mechanisms and capacities to mitigate climate change impacts and adapting to good practices, the following recommendations need to be considered;

Harmonizing activities of different initiatives

Following the prevalence of climate changes and its impacts in the basin and continent at large, many initiatives have embarked on formulating strategies and plans geared towards mitigating impacts of climate change. There is a need to develop a coordination and linkage mechanism to optimize resources and harness synergies of these different initiatives.

Implementation of strategies and plans for climate change issues

Many strategies and plans for mitigation of climate change and its impacts have been formulated but for some reasons, including lack of capacity, have not been implemented. There is need for implementation of these plans.

Need to customize global practices to local conditions and explore traditional methods of adaptation

Customization of global practices to local conditions is important in addressing climate changes challenges in Africa. Effort should be invested in downscaling and customization of global practices

Global adaptation practices may not necessarily be substitutes for indigenous knowledge and practices. There is need to research and examine the traditional methods in Africa before the global methods are fully embraced.

Need to domesticate models

The common trend in global breakthroughs has been championed by the west. The bio-physical environmental conditions in Africa are complex and need targeted attention. Though parameters may generally be similar on the global scale, specific examination of these parameters and wise use of the models need to be given attention.

Funding of climate issues in the national budgets

The funding of the climate sector is low in most developing countries. In order for the sector to thrive, there is a need for commensurate financial support especially in key basin areas such as establishment of a formidable and motivated human capital, development of technical capacity like data collection and analysis and forecasting.

Capacity building (human, institutional & systemic)

The capacity of institutions needs to be enhanced to cope with the evolving challenges in climate change. The human capital needs to be enhanced to cope with the advancing technology and adequately cover the continent. The institutional capacity in terms of management of climate change needs to be enhanced at all levels in most African countries. Lack of equipment and management tools to effectively manage the climate sector is a problem in most countries. There is lack of adequate coverage in terms of systems related to climate change. There is need for robust early warning system to curb the impacts of climate change and promote adaptation practices.

Need for realistic Adaptation strategies: Some demonstration projects /programmes – Community based

Some adaptation strategies are difficult to assimilate in the local communities of Africa. This could be explained by cultural or social backgrounds of the respective communities. There is a need to provide for demonstrations in formulating strategies and action plans for adaptation.

Policy issues: Climate, society, environment and economy

Considering the transboundary nature of the climate change issues, there is need for harmonization of the policy issues in climate change to accommodate the transboundary dimension. Besides the transboundary harmonization, there is need to assess and balance the three key pillars that affect the climate.

Strengthening African Institutions: NMHSs; African centres, etc

Regional institutions that promote climate issues need to be strengthened and provided with adequate support. These institutions are responsible for the regional overview of the climate issues and are key elements in coordination of the climate issues on the regional scales. Further, at the national level national meteorological services need to be adequetly supported to enable them provide the information.

Education and awareness

There is need to educate and raise awareness in the areas of climate change. Strategies aimed at improving understating of climate change issues need to be formulated. Understanding of mitigation measures and adaptation practices need to be understood at the community level.

Monitoring and evaluation of plans to addressing climates change issues

There is an apparent lack of a clear monitoring mechanism regarding the level of effectiveness of the intervention at the different layers of interventions. There is a need for a coordinated move to assess the impact and refine the use of the resources.

The Nile Basin Initiative has developed a concept note to initiate project to mainstream climate change in NBI projects and programs. The project will be implemented in four phases. The first phase will consist of Preparation/stock-taking and is estimated to cost US$300,000. This phase is expected to last for no more than 6 months and will consist of an in-depth identification of current initiatives related to the assessment of climate change impacts, adaptation and measures undertaken within the boundaries of the Nile basin by development partners, riparian and other external entities. The subsequent phases consist of : Downscaling general circulation models, scenario development (US$ TBD, 2 years) ; vulnerability assessment and emerging opportunities and adaptation measures and policy options for the Nile (from year 2 of assessments) . The cost of the three phases will be evaluated once Phase one is completed and the report is endorsed by all key stakeholders.

References

Minutes of the 26th Nile Technical Advisory Committee Meeting

Baxter, JM & Buckley PJ and Wallace CJ, eds. (2008), Marine Climate Change Impacts Annual Report Card 2007–2008, Lowestoft: Marine Climate Change Impacts Partnership

IPCC. (2007) Climate change 2007: the physical science basis (summary for policy makers), IPCC.

IPCC. (2007) Climate change 2007: Impacts, Adaptation, and Vulnerability. Contribution of working group two to the FAR of the IPCC

United Nations Convention on Climate change, United Nations, 1992 http://unfccc.int/resource/docs/convkp/conveng.pdf

Chapter 12

Nile Basin Discourse

Climate Change Adaptation and Transboundary River Basin Management – The view of an NGO

By F. C. Oweyegha-Afunaduula. Chair, Nile Basin Discourse. Makerere University. Kampala, Uganda

Contents

1. Introducing Nile Basin Discourse

Nile Basin Discourse (NBD) is an international transboundary non-governmental organisation (NGO) operating in 10 countries of the Nile Basin (Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Tanzania, Sudan and Uganda) and registered as such in Uganda. It was formed in 2002 initially as a collaborative effort between the Canadian International Development Agency (CIDA) and the International Union for the Conservation of Nature (IUCN).

The headquarters of NBD are in the same town - Entebbe in Uganda - as the NBI, formed almost 10 years ago by 9 countries of the Nile Basin (Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Tanzania, Sudan and Uganda), primarily to spearhead socio-economic development. This was a strategic location, or vantage point, from which NBD was to bring civil society concerns, fears, hopes and expectations to bear on the transboundary projects and programmes of the NBI and influence the quality, relevance, accountability and effectiveness of the Initiative to deliver.

Structurally NBD consists of 10 Nile Discourse Forums (NDFs), one for each country, which are interlinked to form a network. Thus we have Burundi National Discourse Forum (BNDF), Democratic Republic of Cong National Discourse Forum (DRC-NDF), Egypt National Discourse Forum (EgNDF), Eritrea National Discourse Forum (ErNDF), Ethiopia National Discourse Forum (EtNDF), Kenya National Discourse Forum (KNDF), Rwanda National Discourse Forum (RNDF), Tanzania National Discourse Forum (TNDF), Sudan National Discourse Forum (SNDF) and Uganda Nile Basin Discourse Forum (UNDF). At least 7 of the NDFs are registered entities under the laws of the respective countries. Each registered NDF can recruit members, pursue its aims, raise funds, operate and network independently of or with NBD, NDFs and other civil society organisations, governmental organisations, intergovernmental organisations, private sector organisations, et cetera within and between boundaries of the Nile Basin countries and beyond. Currently, through the recruitment efforts of the NDFs, NBD has well over 1,300 member NGOs throughout the Nile River Basin.

It may be said that NBD was a product of an emerging school of thought in global development dynamics which held that to effectively manage transboundary natural resources, such as international waterways, it was necessary to create an international Nile Basin Discourse and integrate it in a web of solidarity and reciprocal roles, together with governments, intergovernmental river basin organisations (IGRBO) and communities, among other actors.

NBD is aware of the increasing global, continental and regional interest in the effective management of river basins, the growing chain of international intergovernmental river basin organisations and the attendant civil activity and concerns. We now know that we are among the few international non-governmental transboundary organisations in the world trying to push the agenda of civil society in transboundary river basin dynamics and development.

The top civic leadership of NBD was, therefore, happy when it was invited to attend the Entebbe (Uganda) Regional Seminar on "building adaptive capacity: mainstream adaptation strategies to climate change in managing African transboundary river basins". Climate change, like environmental change, can affect virtually everything negatively, including river basin management, the effectiveness of development and civil society community empowerment and engagement in the effective governance and policy influencing of the river basins.

2. Climate Change: The Case of Africa

Climate change strategies are today typically framed by two broad approaches: mitigation, which encompasses efforts to reduce climate change itself, and adaptation, which encompasses activities to manage those effects of climate change that are inevitable despite mitigation efforts. This framing aligns closely with the public health framework of prevention and preparedness. Like prevention, mitigation seeks to prevent negative outcomes. Like adaptation, preparedness acknowledges that, while not all negative outcomes can be prevented, they can be reduced and managed (HSCEIGW, 2008).

Adaptation is a relatively new concept in Africa. Both research on climate change adaptation and implementation of adaptation actions have yet to make their debut on the continent in general, and the transboundary river basins in particular. Elsewhere, however, the vulnerability approach, which is based on the concepts of vulnerability and adaptive capacity, is the principle method being employed for determining and choosing adaptation options. Unfortunately, even in those countries where some progress has been made, ignorance of the vulnerability of different types of infrastructure and of what potential impacts new engineering requirements, codes and standards will have on climate change, vulnerability still persists.

Climate change adaptation research is needed in as well as between and across all sectors, including infrastructure such as water, transportation, energy, communications, buildings, and solid waste management. However, building capacity for climate change adaptation research must take place within the context of a broad policy development process for whole transboundary river basins. Long-term commitment to capacity building and new, flexible, funding initiatives are required.

Although adaptation is expensive it is absolutely critical that actions such as analyses of infrastructure failures; regular infrastructure maintenance; community disaster management planning; updating climatic design values, engineering codes and standards; and improving the quality and length of climate data records are undertaken in Africa. It is in Africa where development failure, apart from being traced to faulty planning or no planning, and corruption, may also be traced in the absence of climate change adaptation research and implementation of adaptation actions. Almost 73% of all large infrastructure projects supported in Africa over the years by the World Bank have tended to fail (Oweyegha-Afunaduula, 2006; www.afuna.org).

Efforts are, nevertheless, underway to ensure that climate change adaptation is mainstreamed in development in Africa in general and in the transboundary river basins in particular. There has been a systematic transition to these efforts: From the recommendations of the African Ministers' Round Table on Climate Change "Towards Stronger Response to Threats of Adverse climate Effects' held on 16-17 November, 2007 in Jinja, Uganda, over the regional seminar at the Imperial Botanical Beach Hotel Entebbe, Uganda, in May 2008, on climate change -mitigation and adaptation, to the August 17-23 2008 World Water Week Commission on Climate Change and Development (CCCD) seminar on Climate Change, Water and Development -Adaptation in Africa, all of which have been financially mediated by donors.

Behind all this is what may be called the politics of mitigation an adaptation. This politic is attractive because it does not challenge the status quo. It excludes a solid politic of solidarity against climate change and prefers to mitigate or adapt to the change once it has occurred. As a consequence the right to development in a climate constrained world is being more and more violated, especially via large infrastructure development.

Vordzorgbe (2007) writes that mitigation refers to limiting global climate change through human interventions to reduce sources or enhance the sinks of greenhouse gases. This way, mitigation aims at improving long-term climate patterns by reducing the hazard of climate change impacts. He defines adaptation as "adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts". Thus, adaptation aims at moderating the adverse effects of climate change by reducing vulnerability to climate effects through a wide range of interventions. However, mitigation and adaptation are not mutually exclusive in responding to climate change effects: Both are necessary in addressing climate risks but the choice of either approach, or their optimal combination, depends on several considerations, including the underlying nature of climate risks, the development context of decision-making and time-lags to realise benefits of implementing the specific approach (Vordzorgbe 2007).

In terms of climate change, adaptation/preparedness is more broadly accepted as a public health activity. However, there is also a role for public health to play by articulating the health implications of climate change mitigation options, both by highlighting co-benefits to health of certain options and by identifying potential negative health outcomes of other possible mitigation strategies (HSCEIGW, 2008).

One writer wrote thus:

"Climate change discussions belong everywhere – in the international negotiations and talks of the United Nations, the International Monetary Fund, the World Bank and the World Trade Organization; in the boardrooms of our world's largest companies; in our classrooms and our living rooms because climate change changes everything, from the food we eat, to the water we drink, our modes of transportation, our methods of heating our homes. It will affect our health and our families. It will change the way we do business and the way in which we govern ourselves, at home and abroad. Preventing catastrophic climate change calls for nothing less than a complete restructuring of the global economy and governance. Individuals can certainly help, but dramatic action by corporations and governments, whose philosophy, practice and choices in development are largely responsible for climate change, are needed to solve the problem".

We must, however, add that governments and corporations alone, or collectively, cannot do so. Civil society action is also needed. Not only is development meaningful when civil society is at the centre of it but preventing, adjusting to and mitigating or adapting to climate change effectively can only be effective and meaningful if all humanity is involved. This is because much climate change starts with people as the cause and ends with people and their environment as victims. In Uganda there is evidence suggesting that with climate change and falling standards of sanitation and basic hygiene, the incidence of dirty water-based environmental diseases (i.e. diarrhoea, dysentery, cholera, typhoid fever, tuberculosis, anthrax and food poisoning) is rising, particularly in the urban and peri-urban areas. To deal with them would require an ecosystem approach, particularly if what we want is climate change adaptation in African river basins (Masundire, 2008). In the whole of Africa major hazards are epidemics, drought, flood, windstorms, insect infestation, famine, earthquakes, wildfires, landslides, volcanos, and extreme temperatures. The most common hazards are epidemics, drought and floods, which together accounted for 79% of all hazard occurrences on the continent during the last century.

There is some evidence to suggest that diseases transmitted by mosquitoes including malaria, dengue and yellow fever, are particularly sensitive to variations in climate. Increased rainfall and floods lead to more surface water, which is used by mosquitoes as breeding pools, and warmer temperatures increases their biting rate, speeds up development of the parasites they carry and widens the geographical boundaries in which they can survive and reproduce. However, the relationship between climate and mosquito populations is highly complex; for instance, higher rainfall can lead to reductions in populations if they wash away breeding pools (HEALTH REPORTER, 2008). The spread of diseases such as malaria is also affected by human activities and their impact on the environment and local ecology, and the incidence of such diseases is determined by the ability of public health systems to provide timely treatment, care and effective prevention strategies (HEALTH REPORTER, 2008).

Long before Europeans arrived in Africa, indigenous peoples of the transboundary river basins survived and prospered because they understood the natural environment very well and how to adapt to its changing conditions. Today, however, climate change is no longer an abstract idea. There is strong evidence, both from scientific data and local observations, that climate change has had, and is having, an impact on every transboundary river basin. Substantial warming and increases in precipitation are projected for the 21st century (Ogden and Johnson, 2002) not only in Africa but also in the rest of the world. Mountains such as Kilimanjaro in Tanzania and Ruwenzori in Uganda that had huge and thick icecaps in the past have lost most of them to climate change.

Due to climate change, infrastructure, power production, transport, biodiversity, agriculture, communities and societies in the Nile basin and other African transboundary river basins are increasingly forced to endure more frequent and extreme weather events, more climate variability and changes in climate norms (average conditions). Numerous climate changes have already occurred. Oweyegha-Afunaduula and Afunaduula (2007) have linked all this to failed development, which they see as a driver of the ongoing environmental genocide at least in Uganda. Elsewhere, Oweyegha-Afunaduula (2008) wonders whether climate change, combined with climate change insensitive development choices do not violate human rights, democracy and justice.

In West Africa, the transboundary river basins are experiencing increasing threat and risks from an encroaching, advancing Sahara Desert. Desertification and the related impacts on ecosystems and human activities now constitute a major threat for humankind, especially if considered in the scenarios of climate change and loss of biodiversity, in Burkina Faso, Chad, Mali, Mauritania Niger, and northern Nigeria.

In the Nile Basin, increases in the mean temperatures, increased rainfall intensity, and increased intensity and frequency of severe storms in many scattered places are becoming common, and prediction of the seasons is no longer precise. In some countries food insecurity and famines are an increasingly constant and persistent reality. These changes are projected to become worse over time. The Uganda Government has recently warned citizens to prepare for floods worse than those that hit Teso region and other parts of the country in 2007. According to Majule (2008) climate change has now become an additional threat putting pressure on already stressed hydrological systems and water resources and is adversely impacting livelihoods of communities in Africa.

Vordzorgbe (2007) has written that promoting climate change-responsive risk management in Africa requires mainstreaming climate factors into development to prevent major impacts of climate change and to promote effective responses to the impacts. However, the tools (knowledge, awareness, policy, finance) are not yet robust or widely accessible and, therefore, need to be made robust and easily accessible for success to be realised (Vordzorgbe, 2007).

3. Barriers to Effective Climate Change Adaptation

The ability to understand climate change and its impacts and, in turn, develop adaptation responses in Africa is hampered by the current virtual absence of climate change adaptation research and monitoring (see also Ogden and Johnson, 2002). However, there is no doubt that climate change is a complex, multi-faceted set of issues. Adaptation processes are also complex. Taking effective action involves both untangling the issues to enable work on specifics such as energy efficiency, and to build understanding of the big picture. It is generally agreed that there is a need for an integrated approach based on sustainable development and with a strong focus on changes to consumption and production. Vision, planning and leadership as well as policy are needed (ANPED, 2008) to effectively tackle climate change and its effects. The great challenge is to ensure sustainability of communities, ecosystems and ways of life in the transboundary river basins of Africa (see also Ogden and Johnson, 2002) by ensuring that development is sustainable.

It is important to recognise that communities in Africa have always adapted to climate and weather by making adjustments for existing climate variability and extremes. With climate change, adaptation requires both adjustments to the present climate as well as to future climates. Climate change research, however, involves innumerable uncertainties and estimations. Our incomplete understanding of climate processes, the interacting scientific and socio-economic variables that influence climate change and the unknown future societal responses to climate change, make it extremely difficult to predict future climate scenarios and the impacts of those conditions on infrastructure. Due to these uncertainties, determining climate change adaptation strategies is a difficult and complex exercise. Furthermore, climate change impacts and adaptation are dynamic, changing over time. Consequently, adaptation necessitates an iterative process.

4. Sustainable Development Versus Adaptation

There is no doubt that adaptation to climate change has the potential to substantially reduce many of the adverse impacts of climate change and enhance beneficial impacts, though neither without cost nor without leaving residual damage. Both natural and human systems need to adapt although they will differ in the way they do so, with the natural systems being reactive and the human ones being proactive. While craving for sustainable development under climate change, however, we need to recognize that experience with adaptation to climate variability and extremes has shown that in both the private and public sectors there are constraints to achieving the potential of adaptation. Although efforts are being made to adopt private, or market-driven, adaptations in all sectors of the economy and various transboundary river basins or regions, these are limited by other forces, institutional conditions and various sources of market failure. As a result the effectiveness of contributions of climate adaptation to sustainable development remains uncertain. It is also important to remember that societies and economies everywhere have been making adaptations on account of climate for centuries but this has not brought about sustainable development. Moreover the capacity to adapt has varied considerably among regions, countries, and socioeconomic groups as well as over time.

It has also been noted at many fora that the ability to adapt and cope with climate change impacts is a function of wealth, scientific and technical knowledge, information, skills, infrastructure, institutions and equity. Countries with limited economic resources, low levels of technology, poor information and skills, poor infrastructure, unstable or weak institutions and inequitable empowerment and access to resources have little capacity to adapt and are highly vulnerable. Additionally, groups, countries and regions with adaptive capacity that is limited along any of these dimensions are more vulnerable to climate change damages, just as they are more vulnerable to other stresses. Many sectors and regions that are vulnerable to climate change are also under pressure from forces such as population growth and resource depletion. By all standards, the Nile Basin region or countries fall in this category.

Sustainable development may seem to be impossible to achieve, but this is not so if we involve all humanity in pursuing this goal through enhancement of adaptive capacity as a necessary condition for reducing vulnerability, particularly for the most vulnerable regions such as the Nile Basin and it's socioeconomic groups. In essence, the activities required for enhancement of adaptive capacity are essentially equivalent to those promoting sustainable development. They are effective if no one is excluded from participating in and benefiting from them.

Despite the proliferation of transboundary river basin organisations (TRBOs), river basin management continues to be faced with complex problems and issues characterised by ignorance, uncertainty, change, suspicion and lack of confidence and trust. Political, historical, legal and cultural differences, as well as the predominant transboundary river basin management for large infrastructure development and hydropower, confound the web of complexity.

On the whole issues that matter to the broad masses of our peoples such as human rights, democracy, justice and access to clean water, good sanitation, hygiene, health and environmental goods and services have in the past been largely squeezed out of development initiatives that emphasise large infrastructure and hydropower. Despite recent initiatives at regional levels to involve civil society, these issues continue to receive less emphasis in transboundary river basin management efforts. It is rare at global, regional and national forums that are dominated by large infrastructures or the hydropower industry for human rights, democracy and justice to be specifically mentioned. Yet they are, and must at all times be, at the centre of sustainable development ; since they remind us that in any development efforts people, nature and other beings should always be winners rather than losers for sustainability to be achieved.

Exclusion from regional development initiatives, of issues that matter to the broad mass of our peoples continues to make it difficult for TRBOs to pursue holistic development or to balance economic, social, environmental, cultural, ecological, psychological, spiritual and ethical aspects of development for sustainable outcomes; and so complicates climate change issues.

We now know that climate adaptation and sustainability goals can be jointly advanced by changes in policies that lessen pressure on resources, improve management of environmental risks, and enhance adaptive capacity. We also know that climate adaptation and equity goals can be jointly pursued through initiatives that promote the welfare of the poorest members of society by improving food security, facilitating access to safe water and health care and providing shelter and access to other resources. Development decisions, activities and programs play important roles in modifying the adaptive capacity of communities and regions, yet they tend not to take into account risks associated with climate variability and change. Inclusion of climatic risks in the design and implementation of development initiatives is necessary to reduce vulnerability and enhance sustainability. Ensuring that all this is part and parcel of development that is sustainable and benefiting the victims of climate change should be integral to a new agenda of organised civil society such as NBD for sustainable development.

5. Nile Basin Discourse and Climate Change

Transboundary NGOs such as NBD can, and should, play a key role in developing regional and local action on climate change. This includes work on building awareness and moving people and organisations from awareness to action. In the Nile basin, however, such action is largely absent. We have virtually no climate change active NGOs, and climate change networks are only beginning to emerge such as the one in Rwanda. Additionally, climate-focused capacity is virtually absent. Building that capacity needs a targeted programme of skills-building delivered locally, nationally and through regional networks in order to enable NGOs to engage with national and local policy-makers, to encourage behaviour change and to support the development of new projects and the community scale infrastructure that can help tackle these issues and show that change is possible and positive (e.g. ANPED, 2008).

Fortunately NBD is waking up to the realities of climate change. The General Assembly of NBD meeting in Kampala on June 20th endorsed constitutional guidelines allowing the leadership of the NGO to include wider issues such as good governance, human rights, democracy, justice, peace, security, cooperation and climate change in civic actions of the organisation. By extension, issues such as oil development and other industrial extraction developments now fall within the portfolio of interests of NBD.

That this should be the way for NBD to move was confirmed during a strategic planning meeting for the organisation held at the Imperial Botanical Hotel, Entebbe, Uganda, from 8th to 10th October 2008. It was at this meeting that NBD for the first time in its historical development recognized, among others, that there was need for it to have a programmatic approach to climate change. The Chair of NBD has suggested that such a programme could incorporate environmental considerations and be called "Environmental Sustainability and Climate Change Programme".

The reasoning is that NBD, being a transboundary NGO spread in 10 countries all of which are lacking in clear policies to tackle climate change, has great potential to provide leadership, spur networking on climate change through community empowerment and engagement. NBD is beginning to be interested in climate change effects on policy, human livelihoods and a variety of human welfare issues including agriculture, education, sanitation, hygiene, health, security, cooperation and prosperity.

We now believe climate change has the potential to impact on civil society both positively and negatively. We believe that the increasing influence of the concept of climate change on global, continental, regional and national development thinking and dynamics will provide us with new opportunities to interface and interact with others and influence in newer ways, particularly with regard to the issues of water, sanitation, hygiene and health (WASH); large and small hydrodams (SLHDs); clean development mechanism (CDM); alternative energy resources (AERs); climate proofing (CP); climate change mitigation (CCM); climate change adaptation (CCA); curriculum change (CC); policy design (PD); multistakeholder processes (MSPs); environment and development dynamics; environmental planning and management (EPM); sectoral, multisectoral and intersectoral approaches; disciplinary, transdisciplinary, interdisciplinary, crossdisciplinary and non-disciplinary approaches; and the value of hard science, soft science, non-science and civic science in transboundary river basin management. We also believe that with climate change, particularly climate change adaptation (CCA) becoming a driving force in development decision-making, our interactions and expectations from our development partners and vice versa are bound to change.

NBD shares the objectives of the Entebbe regional Seminar on "Building adaptive capacity: mainstream adaptation strategies to climate change in managing African transboundary river basins" of sharing data and information, learning from existing experiences and developing a broad concept to mainstream CCA in RBOs. When we agreed to participate in the seminar, we were convinced that apart from learning from the experiences of such RBOs as the Organization for the Development of the Senegal River (ODSR), Zambezi River Authority (ZRA), Kobwa River Basin Authority (KRA), we shall be able to learn what steps they have taken to mainstream climate change adaptation strategies in the management of their transboundary river basins. We hope to see to what extent civil society organisations and local communities have been integrated in this effort. Being a transboundary NGO, NBD participated in the seminar with eagerness to learn what opportunities have been, or need to be, created for inter-sector, cross-sector and transboundary civil society action and cooperation with others to reduce vulnerability of our poor, agriculture, environment, cooperation, security, et cetera to climate change.

We believed that there was need to enhance the confidence and effective involvement of NGOs in general and NBD in particular in the management of our international transboundary river basins with reduced climate and intellectual limitations. We now know that the participation of local governments, private sector, a wide spectrum of NGOs, civil society institutions and various stakeholders will be necessary to innovate and translate climate change adaptation-focused policies and programmes into actions as well as provide the necessary feedback.

The great challenge we face, however, is that for the majority of our local stakeholders it is still extremely difficult for them to understand regional water management issues in transboundary river basins and become effectively involved in implementing or influencing the innovation of people- or environmentally-conscious water policies such as those needed to deal with climate change. Multistakeholder processes could be extremely useful in bringing together different stakeholders to think together, review issues together and generate easily understood information and strategies together.

NBD and all NDFs have already demonstrated success in initiating multistakeholder processes intended to enhance the involvement and confidence of civil society in the development processes in the Nile Basin region. Unfortunately, lack of financial resources has made the processes unsustainable and, therefore, not a continuous, permanent feature in Nile basin environment and development dynamics. It is critical that NBD and the NDFs have the opportunity and acquire capacity to organise sustainable multistakeholder processes or dialogues on climate change related issues. Because climate change is a new issue to NBD and the NDFs they have yet to initiate climate change-oriented multistakeholder processes. We need to be helped to increase our capacity to do so. We hope that now that we are developing a strategic plan that will put NBD onto the programmatic path in the next five years, we shall be able to marshal adequate financial support to enhance our capacity to deal with climate change. Currently there is increasing donor interest to support NBD with financial resources. A donor conference is planned for early November in either Nairobi or London.

One of the challenges of climate change is that action is needed on many issues and with different approaches. Six issues seem to be focal points for positive action: Energy Efficiency, Renewable Energy, Transport, Water Resources, Waste Disposal and Management; and Biodiversity. There is also the matter of encouraging behaviour and attitude change. All these have clear links to changing consumption and production patterns, and in every case there is a need for the engagement of NGOs and civil society in planning and delivering those changes (ANPED, 2008). NBD and the NDFs can, through workshops, seminars and special short courses organised by themselves or in collaboration with other NGOs, or pertinent institutions, raise awareness and instgate action on the various issues and their linkages to climate change. Issues such as Environmental Sustainability and Climate Change; Climate Change and Governance; Climate Change and Democracy, Climate Change and Human Rights, Climate Change and Justice, Climate Change and Environmental Health, Climate Change and Food Security, Coping Mechanisms, Climate Change and Desertification and Adapting to Climate Change constitute additional areas in which NBD and the NDFs could be help and have the capacity to establish and organise multistakeholder processes, workshops, seminars, short courses, debates, et cetera as strategies towards improving civil society participation in climate change-conscious transboundary river basin management.

As can be seen, many opportunities emerge for initiative, facilitation and empowerment and engagement of NBD and the NDFs, and by extension of communities, in new ways, to play a more pivotal role in the transboundary management of the Nile River basin.

This is important and timely. Co-management between stakeholders and TBROs offers significant opportunities for all actors to contribute, in a collective manner, to a secure and prosperous future for the peoples and basin states involved, and for basin ecosystems, which should be seen as holistic socio-economic, socio-cultural, socio-ecological and ecological-biological units. NBD and the NDFs can lobby governments (the Executive and the legislature), and even the African Union, for concrete action(s) on climate change; work with local governments on climate change; promote energy efficiency and renewable energy; take action oil exploitation; work with local communities and local governments on adaptation to climate change.

Uganda and Kenya, despite their level of development and poverty have either taken or expressed interest in developing nuclear energy, which could have basin-wide climate change impacts. The area of nuclear energy, therefore, presents new opportunities to NBD and NDFs for advocacy and lobbying. We can help to build an information base and network on nuclear energy and climate change. NBD and the NDFs can begin to make civil society and other actors in the Nile basin embrace the six general strategies (Vordzorgbe 2007) for adapting to climate change, and also to advocate that the strategies form the basis for developing adaptation responses to be mainstreamed into development instruments of the Nile basin countries. The six strategies are:

- Preventing losses, for example increasing the resilience of infrastructure and physical development or reforesting degraded hillsides
- Reducing losses to tolerable levels, such as improving management of climate-sensitive natural resources and economic production systems, promoting economic diversification to reduce over reliance on climate-sensitive primary industries, and emphasizing agricultural processes that gua-

rantee minimum yields even under the worst conditions
- Sharing or spreading risk, to ease the burden on those directly affected by climate change such as through insurance or disaster assistance
- Changing a use or activity that is no longer viable, such as retrofitting a thermal power station with combined cycle gas turbines to enhance conversion efficiency
- Changing the location of an activity, such as re-siting critical service infrastructure
- Restoring sites, such as reclamation of degraded coast land.

To this end, NBD and the NDFs should not be too shy to lobby and advocate against development philosophies, attitudes and practices that practically render these strategies untenable. They should be conscious of the current philosophy of "development first and environment next", and the increasingly dangerous culture of quick-fixing and fast-tracking undesirable projects, land grabbing and the new ownership society (NOS) that encourage the rich and powerful to dispossess the poor, and together are behind the senseless destruction of natural resources, ecological community governance (CEG) and associated knowledge systems, thereby also making the six strategies untenable, and lobby and advocate against them. Otherwise not doing so will allow anti-sustainability forces, attitudes and practices that will constrain any efforts NBD and NDFs deploy to influence policy and management of Nile basin transboundary river basin and the resources therein.

Ultimately NBD and NDFs should transform themselves into agents of adaptive management in the Nile Basin to facilitate resilience, which, as Vordzorgbe (2007) puts it, is a higher-order goal than adaptation and should be the target of risk management development. This calls for integrating climate change adaptation with disaster risk management. Adaptive management and risk management are complementary in creating and maintaining resilience (Vordzorgbe, 2007).

As part of collaborative action on climate change, NBD and the NDFs can advocate for, initiate or participate in a basin-wide Climate Impacts and Adaptation Research Network operative within and between countries in the Nile basin. They can also participate in the development of National Climate Change Adaptation Frameworks (CCAFs) for each country of the Nile basin.

NBD can participate in the development of a regional transboundary climate change adaptation framework (CCAF). The framework should outline the future agenda of collaboration between governments to address key demands from business and the community for information on climate change impacts and to fill critical knowledge gaps, which currently inhibit effective adaptation. Once in place it should guide action by all levels of government, at least in the medium term by:

- Supporting decision-makers with practical guides and tools to assist in managing climate change impacts
- Establishing a new regional centre for climate change adaptation to provide decision-makers with robust and relevant information on climate change impacts, vulnerability and adaptation options;
- Generating the knowledge to understand and manage climate change risks to water resources, biodiversity, rivers, lakes, agriculture, fisheries, forestry, human health, tourism, settlements and infrastructure;
- Working with stakeholders in key and across sectors to commence developing practical strategies to managing the risks of climate change impacts
- Assessing the implications of climate change and possible adaptations for areas currently impacted by drought or floods

Other opportunities for NBD and the NDFs lie in promoting the use of relevant knowledge, innovation and education to enhance public understanding and response to climate change so as to build a culture of mitigation and adaptation; establishing climate change adaptation learning communities; identifying, assessing, monitoring and warning on climate change and its effects to aid planning and implementing effective climate change adaptation measures; ensuring that climate information is not too technical to understand but is more relevant and useable for disaster reduction; advocating for environmental business, innovative approaches to business support for risk management, monitoring and surveillance of hazards; adopting partnership approaches; contributing to communities in enhanced social responsibility initiatives; preventing secondary disasters; helping to anchor adaptation and mitigation in local circumstances and imperatives, including up-scaling initiatives by local people who demand increased voice and accountability; and thereby promoting context-specific research and learning approaches to deal with the complexity and uncertainty inherent in climate change (e.g. Vordzorgbe, 2007).

6. Futures

Vordzorgbe (2007) emphasised the need for greater, more focused, purposeful and action-oriented public commitment from all, particularly the political, administrative, business, science and technology leadership. He wrote that climate change adaptation is a public good because it provides benefits shared by all. He was of the view that governments have the main responsibility to lead and provide support for adaptation responses by all segments of society. He suggested that a key instrument of public support is a national framework for mainstreaming climate adaptation. According to him, this should specify that the main strategic approach to mainstreaming climate change in disaster reduction is to reduce vulnerability through pertinent and feasible adaptation measures and also embody an enabling environment that promotes strengthening of climate adaptation measures and opportunities for business actions. Mainstreaming climate change adaptation in disaster reduction means integrating it in overall development policies and programmes. He recommended that institutional mechanisms for risk management need to incorporate climate concerns with a long-term perspective in planning and implementing risk reduction actions and that national and local development policy and budget processes should anticipate effects of climate change. He cited two key development frameworks for national level action: Strategies for sustainable development and poverty reduction (SSD & PR) and National Adaptation Programmes for Action (NAPAs) under the UNFCCC. He, however, stated that UNISDR National Platforms for Disaster Reduction constitute an effective institutional mechanism for integrating climate adaptation and disaster reduction in development because they represent multistakeholder and cross-sectoral interests and bring together all stakeholders concerned with disaster reduction at the national level. He is of the view that at the local level, institutions such as community-based organizations (CBOs), sector associations (SAs) and enterprise representational associations (ERAs) involved in development and disaster reduction also provide critical resources for mainstreaming adaptation measures.

In every case, however, climate change adaptation leadership, especially by the political leadership, will be the key to success. However, effective climate change adaptation leadership by organised civil society will also need to be developed, especially to ensure climate change accountability by the political leadership and appropriate institutional development to address the issue of climate proofing effectively well into the future. Even if it is difficult to stop climate change, we can take stopping climate change as a dream or vision and do those things that can be done to take us in that direction, however difficult. It is dangerous to do nothing about climate proofing and instead wait to mitigate the effects of climate change, or take measures to adapt to the undesirable new conditions created by climate change.

We should all encourage the political leaderships in Africa in general and in the transboundary river basins in particular to undertake political, social and technological shifts away from the status quo of climate change-do-nothing so that we become part of a growing movement to stop climate change rather than get more confident that mitigation and adaptation will do. This is not to say that we should not mitigate or adapt to climate change. This is to say that we can do something before there is climate change to mitigate or adapt to.

If we choose mitigation, then this should include ensuring that the clean development mechanism (CDM) is not preserved as an anti-thesis of the Kyoto Protocol on Climate Change, or as a business-as-usual tool for protecting undesirable development choices in the region. At the moment, not only is the CDM blindly subsidising the destruction of rivers, but the dams it is supporting are helping destroy the environmental integrity and development effectiveness of the CDM itself. The CDM is proving to be a latter-day invention for corrupting development via large dams. Large hydro promoting governments, developers and financiers are repeatedly justifying their application to the CDM by stating that projects that would be completed will only be completed if they receive CDM revenue.

NBD is worried that CDM, which continues to be touted as having environmental and sustainable development objective, is in fact emerging to be a failed, discredited, misguided mechanism that is handing out billions of dollars to chemical and oil corporations and large hydro-developers – in many cases projects our leaders would have given full political and environmental support to without CDM, have been made CDM compliant. However, it is an issue around which NBD and the NDFs can weave effective advocacy and lobbying, empower communities and engage them for effective civic participation in the fight against climate change well into the future. We believe that while there is need to increase knowledge among leaders and the led about climate change and its consequences with the aim of innovating methods for identifying vulnerable sectors of society, preparing our people or societies to adjust to future climate and make local plans and actions to counteract climate change, there is even greater need to rethink the knowledge type all together.

Climate change and transboundary river management, being cross-cutting issues, demand that we shift from over-emphasising specialised education and learning (i.e. disciplinary education and training producing disciplinary experts) to emphasising interdisciplinary, transdisciplinary, non-disciplinary and integrative education and training. Such a shift would allow for the production of specialist and generalist thinkers and workers by our institutions of higher learning. These will effectively conceptualise around and address the cross-cutting issues. It is an integrated curriculum we shall need to encourage. Without a cadre of products of an integrated curriculum we shall continue to deceive ourselves that we can deal with climate change or manage our river basins effectively. To produce such a cadre we need to be committed to new institutionalisation, including establishing integrated and integrative universities. NBD and the NDFs can begin advocating for the new institutionalisation and forming networks and coalitions with individuals and institutions already championing it.

Climate change demands that we stop pursuing solutions in a sectoral manner; that we do so intersectorally, transsectorally and cross-sectorally. It also demands that we judiciously balance science and non-science and hard science and non-science and integrate the natural science, social sciences and the humanities and even take civic science more seriously than ever before.

Civic science implies taking indigenous communities and their traditional ecological knowledge seriously and bringing it to bear on or interact with different actors in development including scientists, government leaders, private sector, researchers, intellectuals, et cetera. What all this means is that we must prepare ourselves to learn anew or to unlearn and begin to seek to see the whole picture and not parts of it.

We believe that building adaptive capacity to climate change in managing Africa's transboundary river basins in general and the Nile Basin in particular should include:

- practical endorsement of the World Commission on Dams' strategic priorities, including the need to address the legacy of failure of past dams

- dropping the ideas of additionality and baselines in the struggle to contain climate change and instead promote and support non-hydro renewable energy projects as an adaptive strategy and protection of climate (i.e. stopping climate change)

- abandoning the now politically popular quick fixing, fast tracking and rubber-stamping of undesirable, destructive large dam projects

- compelling project proponents and developers to meet international social and environmental standards by complying with the recommendations of the World Commission on Dams

- a political shift from climate-change-do-nothing, which is hydro-heavy to climate-change-do-something, which is pro-alternative energy resources

- a social shift to accommodate green buildings, green collar jobs and/or creation of sustainable employment opportunities by promoting coalitions of environmental groups, labour unions and politicians/political associations, and supporting youth movements to stop climate change
- a technological shift for new and renewable energy capacity development
- promoting investment in new and renewable energy technologies, including venture capital, project finance and research and development

- Promoting more effective communication (information sharing and training) between climate change researchers, NGOs, policy makers, engineers, architects, operators and asset managers in order to mainstream climate change adaptation into design, maintenance and restoration of infrastructure and develop a strong African message on the effects of climate change and present this message nationally, regionally and internationally.

There is a paucity of information available to assist communities to understand and prepare for climate change impacts. Even less information is available at a scale that is useful to community-level decision-making processes. NBD and the NDFs should brace themselves to help in a big way to create information easily consumable by local communities and communicate it accordingly.

Observations and concerns on climate change vary among and within communities, and community observations do not always mirror projections from models. The projected impacts of climate change are already exacting considerable concern to residents of the transboundary river basins of Africa, due to the potential consequences to the ecology and traditional lifestyles, resource development and conservation (see also Ogden and Johnson, 2002). Again NBD and the NDFs can in the immediate, medium and long-term future play a critical role in documenting the impacts and communicating them far and wide but most specifically to the policy-makers that may be interested in conserving traditional values and lifestyles.

Experience-based ecological knowledge, also referred to as traditional ecological knowledge, offers insights into animal behaviour, ecological relationships and environmental health. It is broadly recognized as a legitimate, accurate and useful source of information. A great deal of local and traditional knowledge about climate change impacts exists, but relatively little of it has been documented. Local observations can complement scientific information, offering a more regional, holistic and longer-term perspective. Local traditional knowledge can also provide a level of regional detail beyond the capacity of current scientific models and analyses (e.g. Ogden and Johnson, 2000). Again NBD and the NDFs can intervene to document the local traditional knowledge since it has value in informing us of how our people pre-adapted to climate change and what coping methods they employed and advocate for its integration in policy development for the management of transboundary river basins.

Being a greatly interdisciplinary issue, climate change adaptation will require an unprecedented level of collaboration by all countries, all sectors and all societies in all and between the transboundary river basins of Africa. However, there will be need to promote less familiar ways of study and research such as integration, interdisciplinarity, non-disciplinarity, transdisciplinarity and crossdisciplinarity in our institutions of higher learning (e.g. Ausburg,2006; Davies and Devlin, 2007). Interdisciplinary studies are at the crossroads (Kleinberg, 2008). A theory (e.g. Newell, 2003) of and resources (e.g. Klein, 2006) for interdisciplinary studies already exist (Klein, 2006) as do evaluation criteria for inter- and trans-disciplinary research. We cannot afford to continue postponing their application to our myriad of interconnected problems, issues and challenges. We have to begin integrating methodologists into teams of substantive experts (Johnson, 2003) that will feel comfortable interfacing and working with transboundary NGOs such as NBD.

There will be a need to innovate appropriate language and communication styles to promote traditional knowledge and improve our scientific capacity to understand climate change impacts on African ecosystems, economies, cultures, traditions and communities; develop and communicate tools that will enable communities to better understand climate change, reduce their greenhouse gas emissions and adapt to changing climatic and environmental conditions; ensure that all new and existing policies, standards, regulations, legislation, and management agreements are consistent with the goal of reducing greenhouse gas emissions and our vulnerability to climate change; establish effective incentives and remove the many barriers to improved energy efficiency and the widespread use of renewable energy; ensure that all institutions, businesses, governments, families and individuals undertake far stronger measures to reduce greenhouse gas emissions; and build capacity by drawing together researchers and the diverse stakeholders, identifying knowledge gaps and research questions, improving access to information, and influencing curriculum change for and providing a stronger voice and visibility to the issue of climate change; and establishing focal points for coordination and communication of climate change information and research results. Clearly these are issues that should attract civic action by the NBD and the NDFs.

Unfortunately, existing and accumulating knowledge tends to be focused more on aspects of economic significance rather than non-economic. Surprisingly social impacts of climate change have received the least amount of research attention. In fact, most of the documented information on this topic merely confirms the lack of knowledge in this area. There are information gaps that need to be filled through a process of communication and community engagement. As noted elsewhere in this article, long-term, regionally focused studies of climate and its impacts on transboundary river basin systems are scarce, and yet they are critical to understanding vulnerability and to developing adaptation responses (Ogden and Johnson, 2002). This is fertile ground for civic or NGO action. Without adequate information it becomes difficult to communicate effectively on new and emerging risks due to climate change (e.g. Dreyer, 2005). Yet participation is a key function of risk communication.

On the other hand risk and uncertainty are inevitable components of science and technology innovation. Under such conditions of high uncertainty and/or ambiguity, risk communication activities will need to include stakeholder and public participation; which are currently best promoted by NGOs in the transboundary river basins of Africa. NBD and the NDFs can engage in education and enlightenment: inform people about risks and their handling; induce behavioral and attitudinal changes: create risk awareness and help people to cope with risks; create trust in responsible institutions: give people assurance of effective, efficient, fair and acceptable risk handling by risk assessors and managers; involve people or themselves in risk-related decisions and conflict resolution; and give stakeholders and representatives of the public the opportunity to participate in risk appraisal and management efforts and/or be included in solving conflicts about risks and their management; identify common values; define compatible visions of "good life"; and find just distribution rules (Dreyer, 2005; Renn, 2005) and communicate accordingly.

Public acceptance to scientific opportunity-seeking will require that risk communication addresses the key challenges of complexity, uncertainty and ambiguity. The involvement of stakeholders and civil society tailored according to these challenges promises to maximize valuable input (knowledge, interests and value preferences) into the risk governance process while avoiding overburdening of the process caused by comprehensive participation on every risk issue. There is a need for institutional arrangements for identifying and addressing value-based conflicts in a pro-active, systematic and direct manner and providing for meaningful public participation (Dreyer, 2005).

The transboundary river basin environment in which global development business now operates will become more complex or challenging due to globalisation, which seems to be the standard-setting or bench-marking criterion. As a result, for transboundary NGOs such as NBD typically operating and influencing across multiple countries, time zones and cultures, effective communication methods are and will be critical as they seek new ways to gain a competitive advantage in development dynamics. Therefore, to greatly enhance their effectiveness and influence on climate change and climate change adaptation in managing the transboundary Nile River basin, NBD and the NDFs will have to take advocacy and communication as the biggest tool they have at their disposal. However, without an effective, efficient advocacy and communication strategy, neither NBD nor any of the NDFs can expect to be successful.

The advocacy and communication strategies should be congruent and reconcilable. It will be more useful if NBD undertakes to develop a universal strategy, which could then be domesticated by the various NDFs. Therefore, NBD needs to quickly initiate the development of an advocacy and communication strategy to provide corporate and basin-wide level guidance to the NDFs to nurture effective interaction, cooperation and networking within and between them and the NBD Secretariat and other publics in the Nile Basin and beyond, on climate related and other issues, problems and challenges. This should be a product of a multi-stakeholder process.

7. Conclusions

Climate change and climate change adaptation are not just technical and scientific concerns. They have historical, emotional, psychological, ecological, environmental, cultural, social, political, corporate and even spiritual dimensions. All the dimensions must be mainstreamed in any strategy, method or framework to deal with both climate change and climate change adaptation. That is to say, human factors are very much at the centre of climate change and climate change adaptation.

Therefore, science and non-science, hard science and soft science, social science, natural science, indigenous science, civic science and the humanities must all be integral to and integrated in initiatives on climate change and climate change adaptation in Africa's transboundary river basins. Interdisciplinary, transdisciplinary, cross-disciplinary, non-disciplinary and holistic science and approaches constitute a credible way forward on climate change and climate change adaptation. It, however, requires that there is a paradigm shift and a rethinking of development all together to take human, political and corporate attitudes and perceptions seriously. We need to start with establishing new institutions, including universities that are integrated and integrative.

NGOs in general and NBD and the NDFs in particular have a critical role to play in mainstreaming climate change adaptation in managing the transboundary Nile River Basin. In doing so, they have to forge alliances, dialogues, multi-stakeholder processes and partnerships with all or some of the actors in the basin, including governments, basin authorities, developers, development partners and communities, among others. hey will also need financial support.

Many opportunities for lobbying, advocacy and even capacity building exist, others are emerging and more could be created by NBD and the NDFs. Of great importance is that NBD and NDFs have the critical role to communicate the risks of development and climate change effectively; ensure that the public is adequately involved in risk assessment and management; identify common values; definition of compatible visions of "good life"; find just resource distribution rules in the basin; and provide civic leadership in climate change adaptation through forging effective, accountable, acceptable, credible and visionary climate change alliances, partnerships, networks and multi-stakeholder processes in the basin.

The ultimate challenge is complex and multifold: Failed development; climate change, dwindling water resources (hydrocide), deteriorating and collapsing infrastructure; advancing desert conditions; social, environmental and ecological, decay, collapse and genocide; poverty wave spread; corporate and political corruption; declining health, sanitation, hygiene, human rights, democracy and justice situation in most of the Nile Basin despite much infusion of foreign aid.

With the advantage of being a transboundary NGO whose jurisdiction and activities are spread all over the basin, and with NDFs as its building blocks, NBD has the unique opportunity of acting as an effective regional civic barometer and providing alternatives, communicating risks and ensuring that local, community, corporate and political initiatives in the Nile Basin do not aggravate the climate change situation further. This opportunity must not be missed. Development partners interested in ensuring that civil society is at the centre of efforts to spearhead the mainstreaming of climate change adaptation in environment and development have the opportunity to do so through transboundary civil society organisations such as NBD. They too should not miss this opportunity. Anything whose time has come cannot be postponed.

Further Reading

Arts, B., M. Noortmann and B. Reinalda (eds.) (2001). Non-State Actors in International Relations. Aldershot: Ashgate.

Ausburg, Tanya (2006). Becoming Interdisciplinary: An Introduction to Interdisciplinary Studies. 2nd edition. New York: Kendall/Hunt Publishing

Auld, H., D. Maciver, and J. Klaassen (2006). Adaptation Options for Infrastructure under Changing Climate Conditions (Toronto: Environment Canada, Adaptation and Impacts Research Group, 2006).

Båge, L. (2007). Climate change: a growing challenge for development and poverty reduction. Published in the official book of the Commonwealth Heads of Government Meeting (CHOGM), Kampala, Uganda and London.

Bouaventura-Cuamba (2008). Challenges to manage floods and droughts in transboundary river basins. Paper at the regional Seminar on Building Adaptive Capacity: mainstreaming adaptation strategies to climate change in managing African transboundary River Basins, 26-29 August 2008, Entebbe, Uganda.

BERRY, J. M. (1999). The new liberalism: The rising power of citizen groups. Washington D.C.: Brookings Institution.

Brand, D. G. (2000). Integrating Landscape Management with Climate Change Issues. Paper presented at the Australian Financial Review Third Annual Emission Forum, 29 - 31 March, 2000, Parkroyal Hotel, Sydney.

Burton, I. , S. Huq, B. Lim, O. Pilifosova, E. L. Schipper (2002). “From Impacts Assessment to Adaptation Priorities: the shaping of adaptation policy.” Climate Policy, 2 (2002): 145-159.

Davies. M. and M. Devlin (2007). Interdisciplinary Higher Education: Implications for Teaching and Learning. Centre for the Study of Higher Education. The University of Melbourne. http://www.cshe.unimelb.edu.au/pdfs/InterdisciplinaryHEd.pdf

Deen, T. (2008). Climate change deepening world water crisis. Inter Press Service
March 19, 2008.

Defila, R., and Antonietta D. G. (1999). Evaluation criteria for inter and transdisciplinary research: Project report, instrument. Panorama Special Issue 1.

Dreyer, M. (2005). Communication of new and emerging risks: A proposal for a stepwise process of stakeholder and public involvement. NEST Conference 2005, 20-21 September, DTI Conference Centre – London.

Hacker, R., A. Bowman, H. Fairweather, D. Hailstones, R. Hegarty, B. Holzapfel, K. Sinclair and B. Williamson (2007). Climate change impacts and priority actions in the agriculture sector: Background paper.

Hays, A. (2001). Who speaks for the poor? National interest groups and social policy. New York: Routledge.

Health Reporter (2008). Climate change and infectious diseases. April 8, 2008.

Henry, S. (2005). Disciplinary hegemony meets interdisciplinary ascendancy: Can interdisciplinary/integrative studies survive, and if so how? Issues in Integrative Studies, 23, 1-37.

House Select Committee on Energy Independence and Global Warming (2008). Climate Change and Public Health. Wednesday, April 09, 2008.

IPCC (2001). Climate Change, 2001: Impacts, Adaptation, and vulnerability. Summary for policymakers. IPCC.

Institute of Biometeorology/ National Research Council (2007). Climate Change and Desertification -Desertification, Environmental Monitoring and Early Warning.16-28 April, 2007.

Intergovernmental Panel on Climate Change (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, P.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22. Available at: http://www.ipcc.ch/ipccreports/assessments-reports.htm

Johnston, R. (2003). Integrating methodologists into teams of substantive experts. Studies in Intelligence 47(1).

Josselin, D. and W. Wallace (eds.) (2001). Non-State Actors in World Politics. Houndmills: Palgrave.

Klein, R.J.T., M. Alam, I. Burton, W. W. Dougherty, K. L. Ebi, M. Fernandes, A. Huber-Lee, A.A.Rahman, C. Swartz (2006). Application of environmentally sound technologies for adaptation to climate change. United Nations Framework Convention on Climate Change (UNFCCC) Technical Paper. Geneva: United Nations.

Kleinberg, E. (2008). Interdisciplinary studies at the crossroads Liberal Education, 94 (1). 6-11.

Knoke, D. (1990). Organising for collective action. New York: Aldine de Gruyter.

Lemmen, D.S., and F.J. Warren (eds) (2004). Climate Change Impacts and Adaptation: A Canadian Perspective (Ottawa: Natural Resources Canada, 2004).

Majule, A.E. (2008). Climate Change and Vulnerability Impacts: mainstreaming adaptations in agriculture and water resource in selected basins. Paper at the regional Seminar on Building Adaptive Capacity: mainstreaming adaptation strategies to climate change in managing African transboundary River Basins, 26-29 August 2008, Entebbe, Uganda.

Masundire, H.M. (2008). The ecosystem approach to climate change adaptation in Southern Africa river basins. Paper at the regional Seminar on Building Adaptive Capacity: mainstreaming adaptation strategies to climate change in managing African transboundary River Basins, 26-29 August 2008, Entebbe, Uganda.

Nelson, P. J. (1995). The World Bank and Non-Governmental Organizations: the Limits of Apolitical Development, (New York: St. Martin's Press and Houndmills: Macmillan Press).

Newell, W. H. (2001). A theory of interdisciplinary studies. Issues in Integrative Studies, 19, 1-25.

Niasse, M. (2008). Climate-induced conflict risks over transboundary water courses. Paper at the regional Seminar on Building Adaptive Capacity: mainstreaming adaptation strategies to climate change in managing African transboundary River Basins, 26-29 August 2008, Entebbe, Uganda.

Ogden, A. and P. Johnson (2002). Climate change Impacts and Adaptation in Northern Canada Briefing Prepared for the Senate Standing Committee on Forestry and Agriculture. Occasional Paper Series # 3 December 2002.

Okon-Nyong, A. (2008). Scenarios on impacts, vulnerability assessments and adaptation in river basin management. Paper at the regional Seminar on Building Adaptive Capacity: mainstreaming adaptation strategies to climate change in managing African transboundary River Basins, 26-29 August 2008, Entebbe, Uganda.

Oweyegha-Afunaduula, F.C. (2004). Interdisciplinarity: the sense and nonsense of academic specialization. In: R. Mukama and Murindwa-Rutanga (EDs). "Confronting Twenty-first Century Challenges: Analyses and Rededications by National and International Scholars". Faculty of Social Sciences, Makerere University: Publisher.

Oweyegha-Afunaduula, F.C. (2006). Dwindling Lake Victoria: can science and the experts avert the looming hydrocide in Uganda? In: NAPE LOBBY, 18th Edition: March, 2006: p. 4-5.

Oweyegha-Afunaduula, F.C. (2006). Security in the Nile Basin in the 21st Century: from military to environmental security. In: SYED A.H. ABDI (ED). "Peace in Uganda: the Role of the Civil Society". ABETO Series No. 3: p. 39-64. Kampala, Uganda.

Oweyegha-Afunaduula, F.C. (2007). Dam-affected Communities: lessons for Bujagali from Swaziland's Maguga dam. Paper at Regional Workshop, Mbabane, Swaziland, 25-27 July 2007.

Oweyegha-Afunaduula, F.C. and Afunaduula (2007). Ecological and environmental genocide in Uganda: Mabira forest and Bujagali Falls. Online www.afuna.org

Oweyegha-Afunaduula, F.C. (2008). Uganda's experience with large dams: past, present, future. Paper Presented at the Regional Workshop on „Dams on the Nile; Lessons Learnt and Future Perspectives" organized by the Sudan Nile Discourse Forum (SNDF) jointly with Nile Basin Initiative (NBI) Capacity Building and Stakeholder Involvement (CBSI) Project, Khartoum, Sudan, 19-21, January 2008.

Oweyegha-Afunaduula, F.C. (2008). Will human rights, democracy and justice survive the new large dam boom? Paper on "Dams, Human Rights, Democracy and Justice" NAPE Documents, Series No. 8, 2008, Kampala, Uganda, June 10th, 2008. Online www.afuna.org

Renn, O. (2005). White Paper on Risk Governance, Geneva: IRGC.

Schulze, R. A. (2008). IWRM as a medium for adapting to climate change. Paper at the regional Seminar on Building Adaptive Capacity: mainstreaming adaptation strategies to climate change in managing African transboundary River Basins, 26-29 August 2008, Entebbe, Uganda.

Shapero, C. R. and E. Di Lorio (2006). Downloading climate change: Municipalities are bearing the Cost. Municipal World, November 2006: pp.27-29.

Smit, B., O. Pilifosova, I. Burton, B. Challenger, S. Huq, R.J.T. Klein and G. Yohe (2001). Adaptation to climate change in the context of sustainable development and equity," in McCarthy et al, Chapter 18 section 7. Available online at http://www.grida.no/climate/ipcc_tar/wg2/654.htm#187 (Accessed Nov. 2006).

SMIT, B., BURTON, I., KLEIN, R.J.T. AND R. STREET (1999). "The science of adaptation: a framework for assessment". Mitigation and Adaptation Strategies for Global Change, 4 (3/4) (1999): 199-213.

Smith, J. B., R.J.T. Klein and S. Huq (Eds) (2003). Climate Change, Adaptive Capacity and Development, (ed.) London, UK: Imperial College Press, p. 9–28.

Tawfik, M.M. (1996). Integrated management of transboundary fresh water resources: Problems and prospects. ECA/MRAG/96/19/TP. Addis Ababa: United Nations Economic Commission for Africa.

Trevin, J.O. and J.C. Day (1990). Risk Perception in International River Basin Management: The Plata Basin Example. Natural Resources Journal 30(1): 87-105

Vidal, J (2005). Climate change and pollution are killing millions, says (World Bank) study. The Guardian, Thursday October 6 2005.

Vordzorgbe, S.D. (2007). Climate change and risk management in Africa: Major issues. Expert Background Paper for the Session on Risk Management and Climate Change. World Economic Forum on Africa, 13-15 June 2007. Cape Town.

Whiteley, P. F., & Winyard, S. J. (1987). Pressure for the poor: The poverty lobby and policy-making London: Methuen.

Wilson, G.(?). "A Great Way to Respond to Climate Change." Urban Design Forum, 76. Appendix 1

Chapter 13

Joint Management of the North Western Sahara Aquifer System (NWSAS)

By M. Ousmane S. Diallo, Coordinator of the Water Programme of the OSS. Tunis, Tunisia
Co-Author: Al-Hamndou Dorsouma, Environment Officer (OSS). Tunis, Tunisia

Contents

1. Introduction

The Observatory of the Sahara and Sahel (OSS) is an international organisation which provides a framework for North-South-South cooperation to mobilise and reinforce the capacity of member countries to tackle the environmental issues they face with a view of supporting sustainable development and combating desertification in circum-Saharan Africa. The main thrust of OSS action is directed at water and land degradation issues.

The geographic area of the intervention of OSS is Africa's arid, semi-arid and dry sub-humid regions (North Africa, West and East Sahel). The mission of the OSS is to assist the member countries and organisations in generating, managing and disseminating information that enhances sustainable natural resources management.

OSS has two main programmes – water and environment, supported by two horizontal programmes – Research for Development, and Information and Communication. The Multilateral Environmental Agreements (MEA) and the major African and international initiatives, and the Millennium Development Goals (MDG), have provided the conceptual framework under which OSS devised its programmes (see Figure 1 for the water programme). By undertaking studies of water and land resources, OSS takes a holistic approach to natural resource management. The programmes allow OSS to fully understand the water and land aspects in its region of action; a region where land degradation and, increasingly, abstraction of water resources pose considerable challenges to sustainable development. Both water and environment programmes are based on solid scientific priniples, reinforced by knowledge of the circum-Sahara's idiosyncrasies and insights from the Research for Development programme. The latter cuts across water and land aspects, to providing a scientific edge, thus the need for an observatory and think-tank working for the benefit of the Sahara and Sahel.

OSS believes that knowledge sharing is a key prerequisite for effective natural resource management. The countries in the region should tackle the common challenges they face with a resolute approach, which puts knowledge at the heart of collective decision-making and concerted action.

2. The OSS Water Programme Model

The water programme focuses on shared aquifers and aims at promoting joint management of these precious resources for economic integration and sustainable development in Africa. While there are a number of well established institutions in charge of shared surface water resources (rivers and lakes) in circum-Saharan Africa, there is a pressing need for proper mechanisms to manage in an effective and concerted manner transboundary aquifers which are crucial to the future of the region (Figure 13.2). The specific objectives of the water programme are:

- to promote „basin awareness“ through scientific and technical collaboration among the countries
- to facilitate and develop cooperative frameworks for shared water resources
- to develop common management tools
- to set up legal and institutional frameworks for proper governance of water resources
- to foster international partnership for sustainable use of shared water resources.

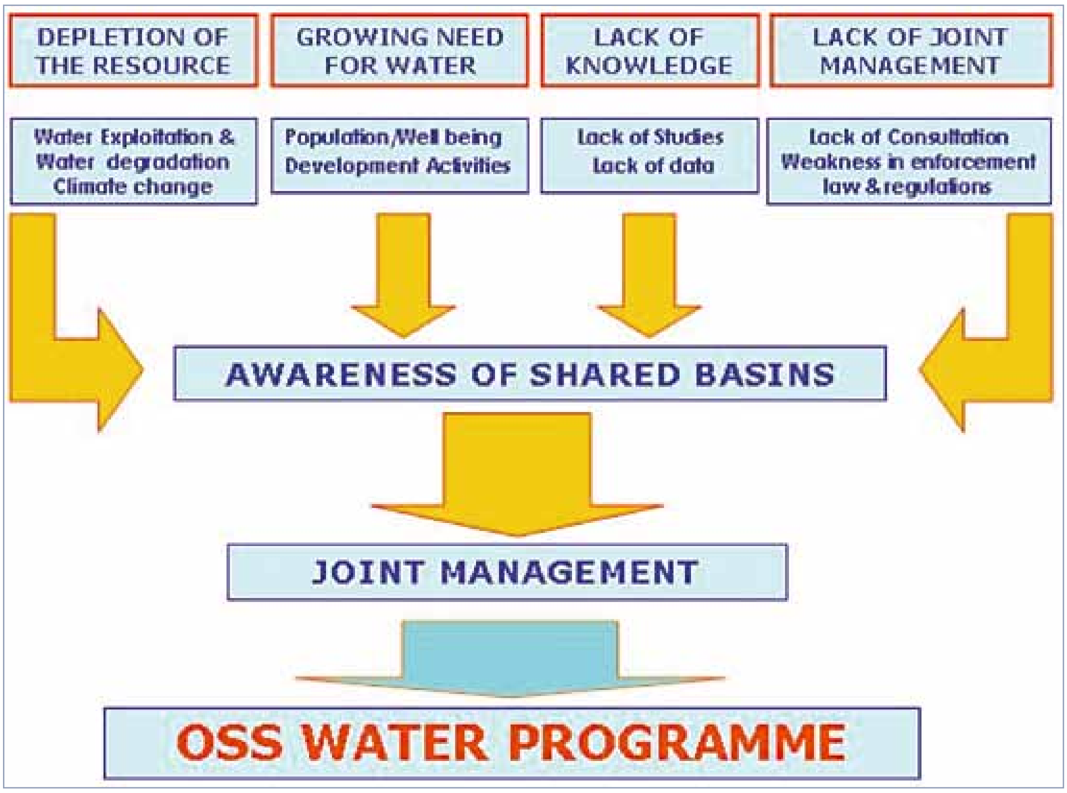


Figure 13.1: The conceptual framework of the water programme

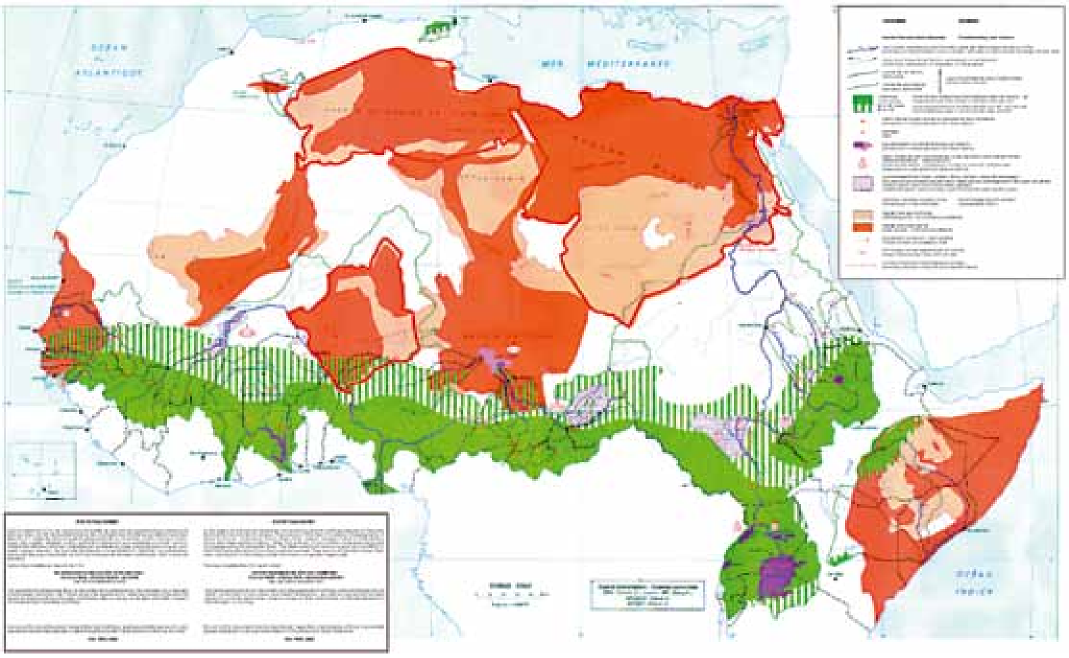


Figure 13.2: Work in progress on major transboundary aquifers in the circum-Sahara region

3. The Characteristics and Key Issues on NWSAS

The North Western Sahara Aquifer System (NWSAS) is a transboundary aquifer system shared by Algeria, Libya and Tunisia. It designates the superposition of two main deep aquifer layers: The Intercalary Continental (IC) and the Terminal Complex (TC). The system covers an area of over 1 million km2 including 700,000 km2 in Algeria, 80,000 km2 in Tunisia and 250,000 km2 in Libya (Figure 3).

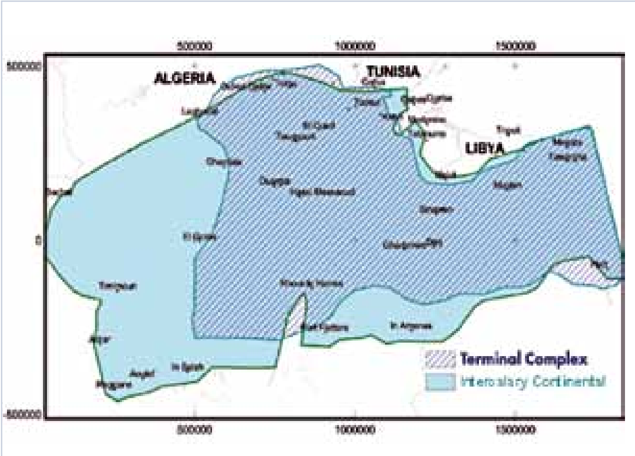


Figure 13.3: The two main deep aquifer layers

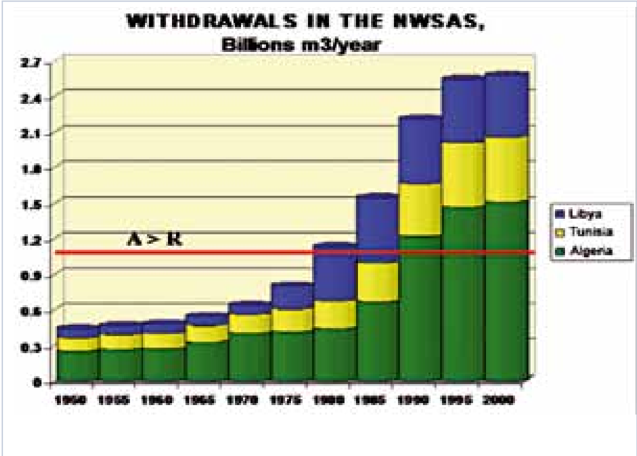


Figure 13.4: Yearly abstraction per country

mean annual rainfall (MAR) ranging from 80 to 250 mm, the formations in the aquifer system are slightly recharged from the following areas: the Saharan Atlas Piedmont in Algeria, the Dahar in Tunisia and the Djebel Nefoussa in Libya. The isohyetal map allows the estimation of the MAR on the whole basin which is about 60 mm per year. In respect of evaporation, even though there are very few precise measurements, it is known to be largely on precipitations, and can be estimated with values ranging from 1,500 mm/year in the north to 2,500 mm /year in the south.

These formations are poorly recharged: The recharge of the NWSAS is estimated to be approximately 1 billion m^3 per year. However, the wide extent of the system and the thickness of its layers have allowed important reserves to be accumulated over the past centuries. The reserves have been estimated at more than 30,000 billion m^3.

About 9,000 water points exploit the water resources of the NWSAS; the number of water points growing as water demand increases. The amounts abstraction also indicate a growth over the past 20 years: From 1 billion m^3 in 1980 to about 3 billions m^3 in 2008. In 1990 the abstraction rate was about 1.5 billion m^3 and so outweighed the mean annual recharge rate of 1 billion m^3 (Figure 13.4). The increasing and intenser abstraction with time has strongly modified the situation by introducing a number of major risks: Strong interference between the countries, artesianism reduction, depletion of the natural discharge, increased excessive drawdown and water table fall, water salinisation, etc. thus seriously threatening the sustainability of the socio-economic development in the entire zone.

How then is it possible to exploit the water resources of the NWSAS beyond the recharge rate by pumping in the accumulated reserves within a sustainable management perspective? How can the countries ensure maximum water withdrawals for the region's sustainable development without irreversibly degrading the resource?

It is in these questions that pose the challenges related to the NWSAS water resource exploitation.

4. Key Elements for Joint Management

4.1 The knowledge and information system

During the first phase (1998–2002), the NWSAS project objectives and activities were comprised of many components: Hydrogeology, an information system, an overall mathematical model and a consultation mechanism. The objective was to elaborate a common database for integrating and streamlining all the surveyed information, in addition to new data collection, integration and updating. Fulfilling such an objective required that the national databases be adapted and homogenized. This implied homogenized data structures and codifications, a GIS interface and the developing of an access module for the digital model.

The Information System (IS) (Figure 13.5) design included the diagnosis, design and realization of a common database, with the objective of making IS accessible simultaneously in the project's headquarters and by each water administration in the three partner countries. The diversity and multiplicity of operations carried out at the 9,000 water points within the network, allows an idea of the amplitude of the task. The obtained information system allows updating of data in addition to performing statistical tests, graphicaly depicting the information and checking model connections. The system contains all the basic elements to establish the monitoring control panel and basin water exploitation. Currently, there is a very good quality management tool operating in each of the three country administrations. At the same time, a map server has been developed to ensure a geo-referenced representation of the available information. This multilayer, thematic representation acts as a decision support tool for planners and makes it possible to go beyond the national framework and to better appreciate the impact of exploitation. The map server is available at http://www.geosass.oss.org.tn/geosass

The project's second phase (2002–2006) focussed on advancing the fruitful cooperation and identifying those technical tools that would lead to a permanent consultation mechanism. In addition to continuing the work on hydrology, information systems and consultation mechanism, the project also stated to address the socio-economic issues of the environment and their relation to resource mobilization in the NWSAS.

The third phase of project is about to start with the aim of furthet improving the management tools and advancing the socio-economic and environmental aspects by use of remote sensing technology to estimate irrigation water consumptions as well as sustaining the consultation mechanism.

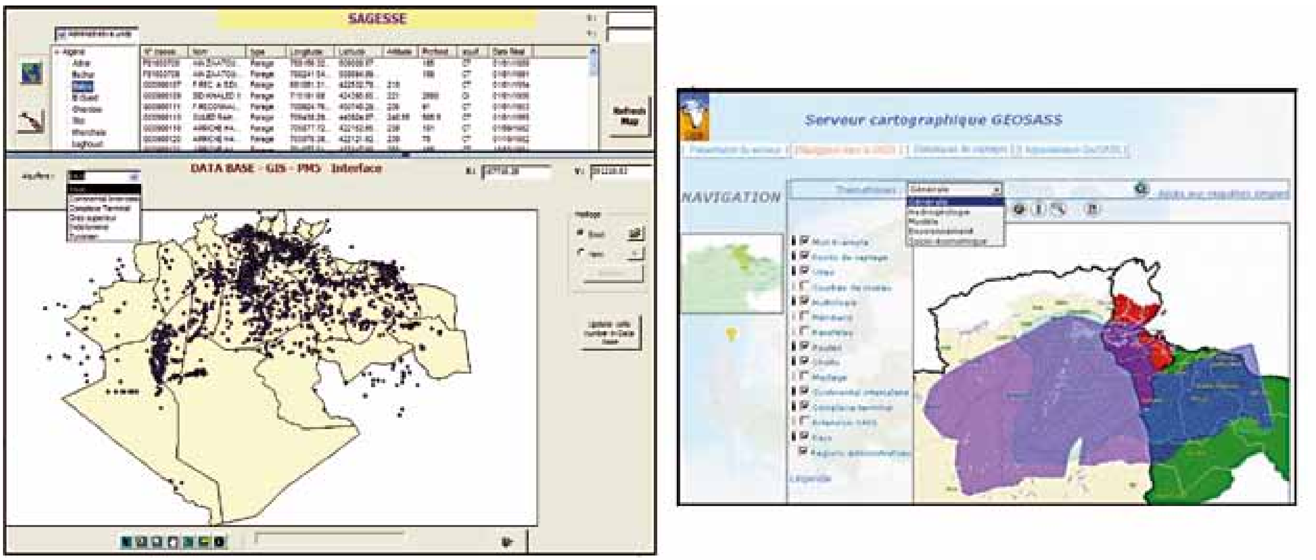


Figure 13.5: The Information System: Data Base, GIS and Map server GEOSASS

4.2 The aquifer consultation framework

The practice of partnership within the NWSAS project has gradually fostered mutual trust between the technical teams; the conviction that common actions increase solution efficiency, and the certainty that information exchange, the foundation of all solidarity, have become not only possible but necessary. The scientific work has enabled the three countries to exchange and build a concerted management. They have gradually defined the form and modalities of such frameworks, culminating in the formal creation of a consultation mechanism and its Secretariat hosted by OSS in Tunisia. The main steps towards the creation of the consultation mechanism were:

- 1999: Initial deliberations and talks on a regular technical management structure
- 2002: Three national workshops to achieve convergence and consensus; design of the structure and the mission
- 2005: Ministerial Declaration and its official adoption by the countries
- 2007: Agreement on the final structure, operation and funding modalities; Appointment of the Coordination Unit Coordinator (Figure 13.6).

The mission of the NWSAS Coordination Unit is to:

- Support the countries in implementing the main technical activities aimed at facilitating consultation, especially data collection by establishing joint networks and updating common databases and models.
- Simplify the institutional process by identifying transboundary water resources challenges, formulating proposals for solution, and formalising consensus and consent.
- Ensure, on the one hand, information dissemination and organizing discussion at the level of decision-makers on programmes and development options in the basins, and promote participatory management through real communication work.

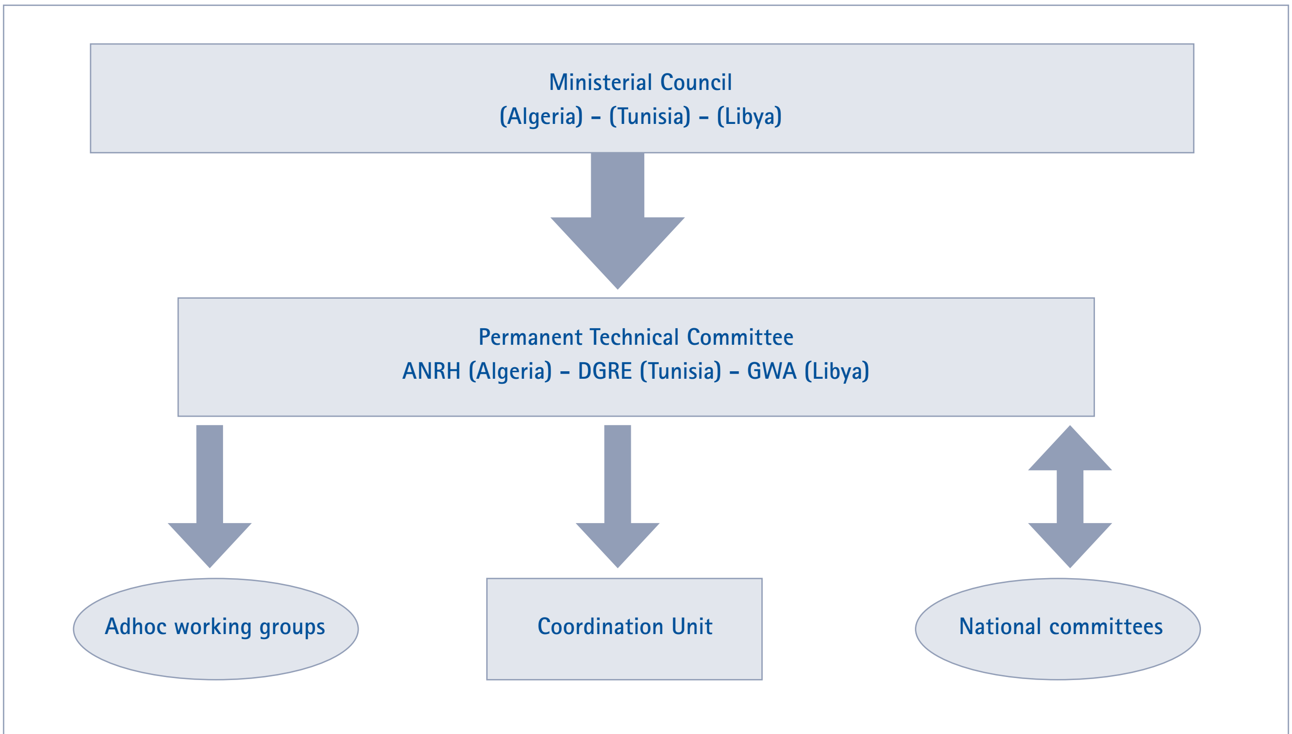


Figure 13.6: The Consultation Mechanism structure

5. Adaptation: A Crucial Issue for the Joint Aquifer Management Strategy

Climate change and variability has many impacts on water resources, and the situation is expected to deteriorate in the future. Many people within the water sector are aware that climate change is affecting water resource management, but they are unsure how to incorporate climate information into their management structures.

Adaptation remains an important option to address the impacts of climate change, in particular in the dry regions where water management is a major concern.

The joint aquifer management approach developed by OSS in Northern, Western and Eastern Africa aims to highlight the important role of adaptation and the necessity of concrete actions to address the impacts of climate change on water resources in the region.

In Northern Africa where water is becoming scarcer and while water demand is growing, groundwater plays a key role in climate change adaptation because of its strategic importance to help meet domestic, agricultural and industrial water demands. This importance will intensify substantially over the next few decades.

Population growth and economic development will place considerable reliance upon groundwater if Africa is to meet the Millennium Development Goals. In such a context, groundwater will play a pivotal role to help increase food production and overcome the threat to food security posed by more variable rainfall as a result of climate change. Adaptation to climate change in North Africa is a major issue from the perspectives of food production, rural population stabilization and distribution of water resources.

In North Africa, adaptation occurs ina context of high development pressure, increasing populations, water management that is already regulating most of available water resources and agricultural systems that are often not adapted to local conditions. In order to address climate change issues in Northern Africa, adaptation for the groundwater resources requires concerted actions as presented below.

5.1 Scientific knowledge and communication exchanges: A prerequisite for establishing efficient adaptation strategies

Major gaps exist in the knowledge of groundwater resources in the region. In respect of the dependence on ground-water in North Africa and the considerable impacts of climate change, it is urgent to improve this knowledge. Bridging these gaps requires greater investment in interdisciplinary research on the relations between groundwater and climate, on training and capacity building, in particular in water policy and management, and on the assessment of climate change impacts on water resources including information exchanges among decision makers, managers and scientists.

It is, further, necessary to develop a strong and clear communication between scientists and decision makers in order to bring transboundary aquifer management to a high political level. Therefore, awareness raising and knowledge management to facilitate transboundary cooperation will provide a common strategic vision and actions for implementation of the adaptation strategies both at the regional and national level.

A sound and reliable scientific knowledge should constitute a prerequisite for establishing efficient adaptation strategies and a solid basis for political decision-making regarding groundwater management.

5.2 The role of the transboundary cooperation

The transboundary groundwater cooperation is important in the context of climate change; for all in resepect of forging and strengthening partnerships between countries which share a common groundwater resources. This implies the institutionalization of the groundwater management at the regional level (through the basin organizations) and at the national level (by the governments through appropriate regulatory and administrative arrangements). Such partnerships could involve governments, developers, managers and regulators, communities and other stakeholders (water users for instance). This cooperation becomes important for the monitoring and management of the groundwater resources.

Transboundary cooperation is a fundamental issue in helping to address the impacts of climate change on groundwater resources in North Africa, as most of these resources are shared by different countries. It is the case of the North Western Sahara Aquifer which requires a significant implication of all the concerned countries (Algeria, Libya and Tunisia). A consultation framework is already established in order to build the cooperation between the countries. This framework has to be reinforced and institutionally adapted to the new challenges posed by climate change.

The technical and methodological support (expert analysis, groundwater data base, mathematical model) must be also further developed, by integrating the existing tools and techniques of assessment of the vulnerability to climate change. Setting up a transboundary cooperation framework should take into account these technical and methodological implications.

5.3 Necessity of financial support

In order to reinforce long term support for the groundwater resources sustainability, there is a need for appropriate financial resources for the groundwater management, both by national budgets and bilateral and multilateral cooperation. This financial security is necessary for groundwater resource exploration, evaluation and sound data collection to bridge data gaps and so allow sound knowledge-based management practices. Financial resources are crucial to reinforce the existing initiatives on groundwater management and to develop new and innovative projects.

Adaptation to climate change in the water sector is expected to be a top priority in the region. However, the major problem is the difficulty in estimating the cost of this adaptation.

Financing adaptation to climate change is currently under negotiation in the framework of the post Kyoto process. In this process, and because of their high level of vulnerability to climate change, water resources should constitute an important issue. This financial support for adaptation of groundwater to climate change impacts must concentrate on funding concrete adaptation projects.

5.4 Need of concrete adaptation projects

Adaptation to climate change requires the implementation of concrete projects. In the groundwater sector it is important that these projects cover different aspects, in particular those related to management of water use and water demand. The projects must be focused on the improvement of water conservation, water harvesting and investment options – in particular in irrigation.

In the region, irrigated agriculture is the major economic activity and the main source of incomes of the rural population. This sector is the biggest consumer of groundwater in the region; and is the reason why investments in this sector must be increased: To help farmers develop water conservation techniques and use in the context of future scarcity.

New adaptation projects should also be set up to improve water supply for domestic use. Even if the level of drinking water access is higher in North Africa (more than 90% of the total population) than in sub-Saharan Africa, it remains important to invest in water quality and this remins a crucial issue in the region.

Furthermore, better monitoring and assessment of water could help to improve planning and allocation processes. For such, it is fundamental to strengthen the institutions which manage water resources both at the national and sub-regional level.

Finally, it is becoming ever more important to review policies that promote activities that are particularly vulnerable (e.g. subsides for rainfed wheat production in North Africa), review plans for new infrastructure.

Chapter 14

Scenarios on Impacts, Vulnerability Assessments and Adaptation in River Basin Management in Africa

By Anthony Nyong, PhD. Division of Natural Resources Management. African Development Bank. Tunis, Tunisia

Contents

1. Abstract

Availability of and access to water is fundamental to Africa's development, considering the importance of agriculture to the continent's economy. River basins have been recognized as important geographic entities for managing water resources in the continent. Besides that many of the major river basins in Africa are transboundary, they are also threatened by global environmental changes such as climate change, deforestation and land degradation. This paper argues that considerable attention should be given to the assessment of the impacts of climate change on water resources management in Africa's river basins. Using a case study of the Nile River Basin, the paper shows how water resources availability, energy production and stream flow could be impacted by climate change and draws attention to the implications for sustainable development within the River Basin. It also notes that addressing the challenges of climate change within the basin should also incorporate other non-climatic factors that contribute to the vulnerability within the basin.

2. Introduction

2.1 Background

Availability of and access to water is fundamental to economic development in Africa. However, drought and desertification are regular cyclical phenomena in the continent. About 40 percent of the continent is classified as either arid or semi-arid. Rainfall, along with freshwater availability, is very unstable, uneven and erratic in both time and space. This variability has significantly negative impacts on society and causes widespread acute human suffering and economic damage (van Jaarsveld and Chown, 2001; Hellmuth, et al., 2007). This is principally as much of the Africa's economy, particularly in sub-Saharan Africa, depends on the ecosystem resources. For instance, in Sub-Saharan Africa, the agricultural sector employs 65 per cent of the labour force and generates about 32 per cent of GDP growth on average, and freshwater availability determines agricultural production.

With the growing demand for water through high population growth rates, increased agricultural demand and industrialization, it has become pertinent to explore and implement more innovative and efficient ways of managing the continent's water resources. A paradigm shift from water resources management based on administrative boundaries to hydrological boundaries has been advocated. River basins are important geographical units for considering the management of water resources in Africa. Adopting a river basin approach to water resources management is necessary to maintain a balance between the competing pressures exerted by the need to maintain resource integrity in the long term, against the compelling call for social upliftment and advancement and the need for continuous economic growth and use of environmental resources.

However, the river basin approach to managing water resources poses some challenges, particularly in Africa. First, Africa's river basins are threatened by global environmental change such as climate change, deforestation and land degradation. Climate change undoubtedly is seen as the single most important threat. Climate change drives rainfall patterns and rainfall provides the dominant control, alongside river basin physiography and human interventions, on inter-annual and inter-decadal variability in river flows and hence surface water availability. River flows in major basins in Africa are already experiencing significant variability that challenges the effective management of water resources and results in huge socio-economic costs.

Second, of the 200 or so major transboundary river/lake basins in the world, nearly 80 are in Africa (Figure 14.1). Seventeen of them are considerably quite large, with catchment areas of more than 100,000 sq. km each (Table 14.1). Some major transboundary river basins in Africa are shared by as many as ten countries. Fourteen African countries' entire surface areas fall within one or more transboundary river basins (ECA, 2000). As noted by Goulden et al., (2008), all of these river basins have high levels of variability, in particular the rivers of west and Southern Africa. Three basins can be described as experiencing water stress (less than 1700 cubic metres per person per year) whilst two of these, the Orange and the Limpopo, both in Southern Africa, experience water scarcity (less than 1000 cubic metres of water per person per year). The Nile and Volta basins have the highest average population densities and are approaching situations of water stress.

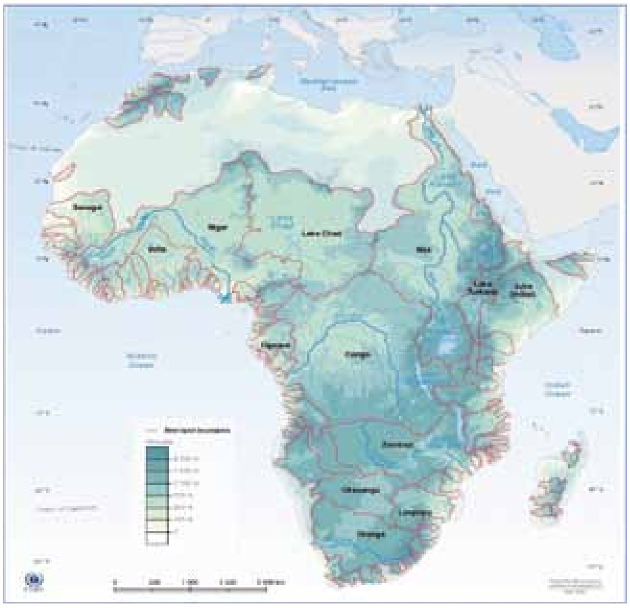


Figure 14.1: Major River Basins of Africa (Source: Wolf et al, 1999)

The potential adverse impacts of climate change on Africa's transboundary river basins underscores the urgency to develop and implement well-coordinated management strategies to avoid disaster and enable the ecosystems within these basins to continue to provide important goods and services to local communities. This will not only contribute significantly to the socio-economic development of millions of Africans living in these basin areas, it will also serve as instruments for inter-country cooperation serving the goals and objectives of the African Economic Community (ECA, 2000).

Name of Basin	Catchment Area (0000 sq. km)	Number of States Sharing the basin	Countries Sharing catchment Area
Congo	3690	9	Congo (Brazzaville), Central African Republic, Democratic Republic of Congo, Angola, Cameroon, Burundi, Rwanda, Tanzania, Zambia
Nile	2950	10	Egypt, Sudan, Ethiopia, Rwanda, Uganda, Kenya, Tanzania, Burundi, DRC, Eritrea
Niger/ Benue	1990	9	Niger, Nigeria, Mali, Guinea, Burkina Faso, Cote D'Ivoire, Benin, Cameroon, Chad
Zambezi	1290	8	Zimbabwe, Zambia, Angola, Namibia, Botswana, Malawi, Tanzania
Volta	390	6	Ghana, Burkina Faso, Togo, Cote d'Ivoire, Benin, Mali
Lake Chad	2370	6	Chad, Cameroon, Niger, Nigeria, Central African Republic, Niger, Sudan
Lake Rudolph	500	4	Ethiopia, Kenya, Sudan, Uganda
Senegal	490	4	Senegal, Mauritania, Mali, Guinea
Limpopo	400	4	Botswana, Zimbabwe, Republic of South Africa, Mozambique
Ogadugue	220	4	Gabon, Congo, Equatorial Guinea, Cameroon
Okavango	320	4	Botswana, Angola, Zimbabwe, Namibia
Orange	800	2	Namibia, Angola
Juba-Shebelli	827	3	Somalia, Ethiopia, Kenya
Ruvuma	140	3	Tanzania, Mozambique, Malawi
Cunen	100	2	Namibia, Angola
Awash	120	2	Ethiopia, Djibouti
Sabie	103	2	Mozambique, Zimbabwe

Table 14.1: Source ECA, 2000

2.2 Current sensitivities of Africa's river basins

The socio-ecological integrity of many river basins in Africa is under serious threat, which could jeopardize the continent's social and economic systems. For instance, the Niger Basin is facing loss of water quality resulting from lack of integrated river basin management. The capacity of Lake Chad is shrinking due to overuse compounded by other hydrological factors, which has put the life of millions of people under threat (Figure 14.2). The Congo River basin, which is the source of about 30% of the continent's water resources, is showing a marked deterioration of quality and flow variation due to the uncontrolled deforestation and other factors related to conflict situations in the basin. Likewise, Lake Victoria is increasingly losing capacity due to siltation and hydrological variations. (Figure 14.2).

Water scarcity is a growing concern in many parts of Africa, particularly in the arid and semi-arid areas. Some countries, particularly in northern Africa, have already exceeded their sustainable water withdrawal levels. Some of these failed to address the institutional and policy context of water resources management in Africa and more effective management of water resources variability will be contingent upon operational capacity of relevant institutions, which in many parts of Africa is weak.

Most of Africa's transboundary rivers and lakes not subject to any agreements on equitable use and/or environmental protection. Few have effective institutional arrangements for consultation and cooperation. For example, of the 80 or so transboundary lake/river basins in Africa, less than 10 percent have any kind of basin-wide agreements and institutional arrangements for the integrated development of their natural resources including water resources. Some large transboundary river basins like the Congo do not have any kind of basin-wide agreements or institutional arrangements. Even in the few basins where such institutional arrangements exist, there is a clear absence of strong political commitment backed by substantive support from their member States.

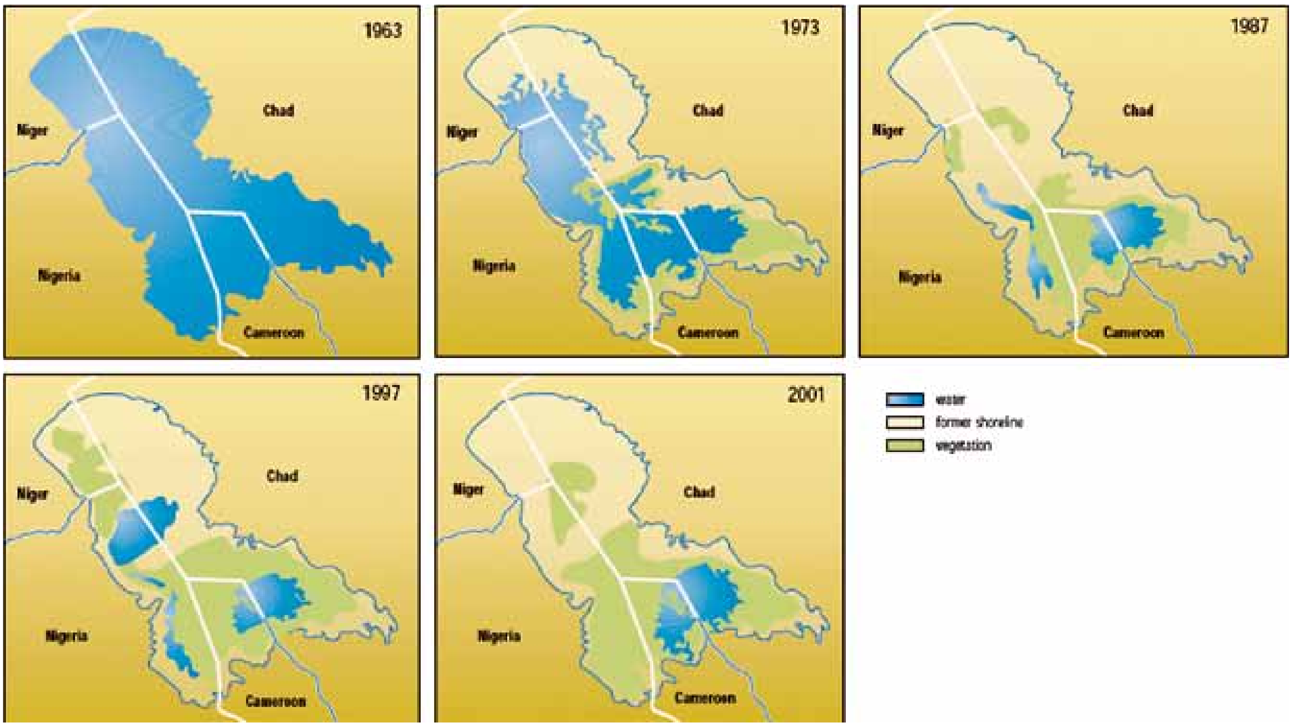


Figure 14.2: Lake Chad

water withdrawals are from transboundary river basins. Water access across much of Africa is complicated by transboundary water management. Because the majority of Africa's rivers flow through multiple countries, cooperation between riparian countries is required for efficient water management and optimal use of scarce water resources. Many interventions have

Many River Basin Agreements in Africa are outdated and predate when climate change was considered an issue (Table 14.2). Current agreements as they stand do not adequately address climate change concerns and could compound the vulnerability of the River Basins as they do not contain effective mechanisms to deal with water use within a changing climate. Procedures for avoiding or resolving international disputes over water are largely lacking. As noted by Niasse (2005), the absence of institutional management of water resources may be the reason for many current conflicts between African countries, and more conflicts are expected as climate change further impacts on water resources and water scarcity in Africa.

Climate change is expected to increase the frequency and severity of water quality/quantity problems in many parts Africa as temperature rises and precipitation show increasing yearly and seasonal variations. Climate change is estimated to worsen Africa's already bad water crisis and more concerted efforts are required to address this and reduce the vulnerability to climate

Name of Basin	Date of Treaty	Number of Countries	Functions
Niger	1964, 1986	9	Assembly of data produced by member states and planning (implementation of projects is carried out by member states)
Volta	1962	6	Provision of energy to neighbouring states (Cote d'ivoire, Togo and benin), agreement on water use with Burkina Faso, Mali and Niger
Mano	1964	3	Coordination of water use, planning, project implementation and operation and maintenance of joint power production projects.
Gambia	1978	4	Implementation by an accord relating to water of the waters of Gambia River and navigation of its waterways, promotion, coordination and execution of studies and works for the development of the basin.
Chad	1964, 1973	5	Planning and execution of river basin projects at both national and regional levels, and regulation of navigation
Nile	1929, 1959	2	Essentially water sharing and supervision of water allocation between two of the ten riparian states (Egypt and Sudan)
Kagera	1977, 1981	4	Planning with wide multi-sectoral scope – including water, agriculture, animal husbandry, minerals, wildlife, fisheries and environmental protection
Great lakes	nd	3	Basically electric power generation under the umbrella of a regional power utility
Cunene	1969	2	Creation of a permanent joint Technical Commission with advisory, study and reporting function
Kariba	1963	2	Vested power previously held by the Federal Power Board in the Central African Power Coo-operation with tasks of implementing new works and the general operation and maintenance of existing works
Komati	Draft stage	2	Creating a Joint Permanent and Technical Committee to plan and regulate the sharing and use of Komati Basin waters and to create an operating agency that will execute and operate major works on behalf of the two riparian states
Senegal	1964, 1972	3	Creation of an organization for the development of the Senegal Basin and other substantive issues
Okavango	1994	3	Establishment of a permanent Okavango River Commission

Table 14.2: Source: ECA, 2000.

change. A decline in the quantity of water, compounded by deterioration in water quality and the occurrence of droughts and floods have strong adverse effects on water-related sectors, including agriculture, industry, domestic use and aquatic ecosystems. Impact from climate change is expected to compound these problems.

The vulnerability of Africa's transboundary river basins is not only caused by climate change but by its interactions with non-climatic factors. In larger water basins and watersheds, the interactions of climate and socio-economic conditions and policies influencing water supplies make it difficult to isolate the role of climate. The complex interplay of social and biophysical factors is also heightening the vulnerabilities and sensitivities of many lakes to a range of changes (including climate change). Overfishing, industrial pollution and sedimentation are degrading local water sources such as Lake Victoria (see for example Odada et al., 2004) and consequently impacting on catches. The multi-species fishery of Lake Victoria has changed to only three species. namely, Nile perch, pelagic cyprinid-dagaa and tilapiine.

3. Climate Change Impacts on Africa's Transboundary River Basins

3.1 Summary of Africa's climate outlook

Models of projected climate change in Africa show that continent-wide temperature increases will likely exceed the estimates of natural variability (Hulme et al., 2001; Boko et al., 2007). The models, under various scenarios, generally project temperature increases over Africa of 2° to 6° C by the end of the century. Overall model results suggest that warming is very likely to be larger than the global annual mean warming throughout the continent and in all seasons. The higher temperatures are likely to increase evaporative demand throughout the continent.

Projections for precipitation show less convergence. However, there is a general consensus that northern and southern Africa will become drier, while the eastern and western regions of the continent will likely experience a significant increase in precipitation. The seasonal and spatial patterns of changes in precipitation will vary considerably. In equatorial Africa, Dec - Feb precipitation is estimated to increase, while near the Horn of Africa Jun - Aug precipitation will likely experience significant decreases. There is some uncertainty about whether additional rainfall in some regions will lead to greater availability of water resources for consumption and production. Climate models also project the occurrence of more extreme events such as droughts, storms and floods. The increased intensity and frequency of cyclones, accompanied by sea level rise will cause problems for coastal cities and major river delta areas.

It is likely that extreme events are going to be the greatest socio-economic challenge. Whilst sub-Saharan Africa is generally associated with drought-related impacts, there appears to be greater frequency and spatial extent of damaging floods in some river basins. Recently, major floods have occurred in eastern Africa, broadly supporting IPCC projections of increases in autumn and winter rainfall (IPCC, 2007; Christensen et al., 2007). These floods have caused major socio-economic disruption where they have occurred (Christie and Hanlon, 2001; Conway, 2002). Some African countries have experienced floods and droughts simultaneously the same year (Boko et al., 2007). As climate change becomes increasingly manifest the prospect of shifts in river flows and variability calls for better understanding of the drivers of variability, rainfall-runoff interactions and how to manage the variability.

3.2 Climate change impacts on river basins

One basin parameter that is most threatened by climate change is river flow, which in turn affects water availability and lake levels. Several studies have examined the relationship between climate parameters and stream flow and concluded that rainfall is the main driver of much of the observed variability in river flows, particularly in the large river basins (Hulme et al. 2001, Conway, 2005). Significant increase in rainfall in East Africa during the short October-December rains is often associated with the El Niño-Southern Oscillation (Saji et al., 1999; Webster et al., 1999). The large decline in many West African river flows is primarily attributed to the effects of the prolonged drying in the Sahel (L'Hôte et al., 2002; Dai et al., 2004). A recent study by de Wit and Stankiewicz (2006) has shown that a 10 percent decrease in precipitation in regions that receive less than 1000 millimetres per year would reduce drainage by 17 percent, in regions receiving 500 millimetres or less per year, such a drop would cut 50% of surface drainage. Depending on the actual hydrological conditions, the effects of rainfall variability on the hydrologic response will generally translate into delayed responses in lake and wetland systems. Particularly, semiarid river basins often exhibit low runoff coefficients and high sensitivity to rainfall fluctuations (Nemec and Schaake, 1982; Li et al., 2005).

Other studies have modelled watershed run-off and drainage density in Africa as proxies for surface flows (Milly et al., 2005; de Wit and Stankiewicz, 2006). Projections of future climate impacts on runoff when averaged across multiple climate models suggest relatively modest changes out to the 2050s vis-à-vis the variability observed during the 20th century. Mean changes in runoff of roughly +/- 5 to 30 per cent are also projected by the middle of this century. A decrease in perennial drainage will significantly affect present surface water access across 25% of Africa by the end of this century (de Wit and Stankiewicz, 2006). Empirical analysis of drainage density and its relationship with annual rainfall show runoff increases in East Africa and reductions in Southern Africa (Milly et al., 2005; Christensen et al., 2007; IPCC, 2007)

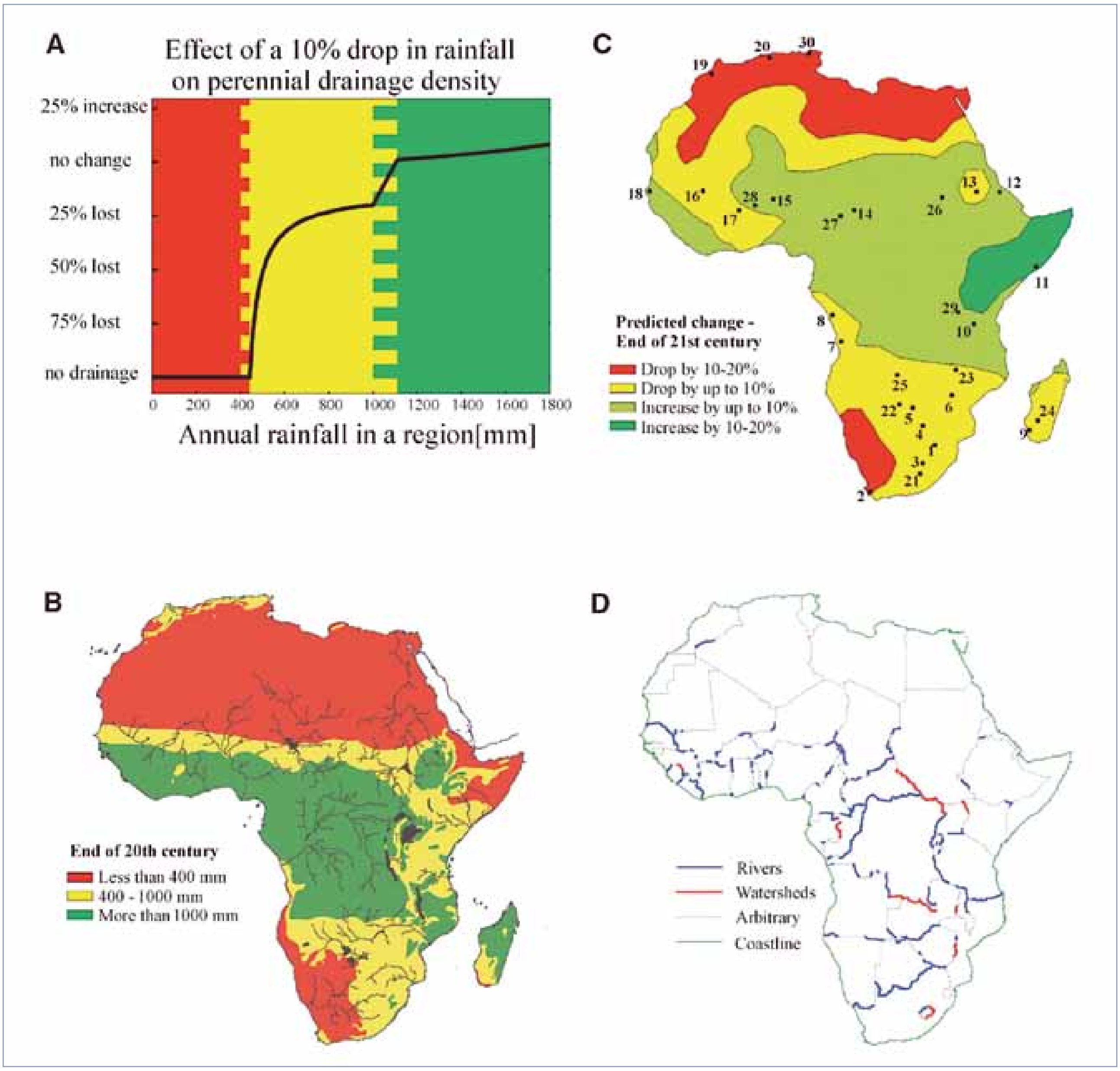


Figure 14.3: Projected Precipitation in Africa (de Wit and Stankiewicz, 2006)

In spite of the large influence of rainfall fluctuations on river flow variability, the response may be influenced by other factors such as the nature of the land surface, changes in land use or land cover, human abstractions, reservoir construction and land surface to atmosphere feedbacks (Savenije, 1996). The impact of climate on water resources is not unidirectional as changes in precipitation patterns and river flow regimes will combine to cause changes in the frequency and magnitude of floods and droughts across Africa in general and in river basins in particular. In coastal areas increasing flood risk will be exacerbated by sea level rise, also caused by climate change. Flooding and drought will have wide-ranging secondary impacts on food security, hydroelectric power generation and domestic water supply (Kundzewicz et al., 2007). There is a high population density in regions exposed to high levels of inter-annual variability in rainfall and runoff. The interaction between declining surface flow as projected by climate change models and the concentration of populations in vulnerable parts of the basins underscores the imperative to integrate climate change into current strategies to manage water resources in Africa's river basins.

For sub-Saharan Africa particularly, robust identification and attribution of hydrological change to climate change is further limited by data limitations and limited assessment of the magnitude and potential effects of other environmental and anthropogenic influences. Knowledge gaps exist in understanding how climate change will affect Africa's river basins in general and the responses to these changes in transboundary river basins in particular. For instance, few studies have considered the effects of changes in variability and magnitude/frequency of extreme events on river flows or on the recharge of groundwater. While the main climate drivers of inter-annual and decadal rainfall variability in Africa are well understood, the same cannot be said of the underlying causes of variability in these drivers and their African teleconnections. These are currently not captured by climate models. Further improvements in the modelling capability within the continent will hopefully improve confidence in model results.

It is also important to note that most of the studies on climate change impacts in Africa are based on large scale Global Circulation Models (GCM). The scales of these models are very large and conceal spatial details that can only be seen and understood at finer resolutions. Therefore, there exists considerable uncertainty about climate change impacts in specific localities such as the smaller transboundary river basins in the continent, which consequently impairs effective adaptation planning. While efforts are being made towards improving climate data, attention has to be paid to improving the capacity of relevant policy makers in the River Basin organizations to effectively understand and use such data to guide policy formulation.

4. Climate Change Impacts on the Nile Basin

4.1 The Nile Basin

The River Nile extends about 6,700 kilometres through a drainage area of approximately 3 million square kilometres and is the longest international river system in the world (Tidwell, 2006). The Nile Basin (Figure 14.4) drains approximately 10 percent of the African continent and is vital to the economic development of the 10 riparian countries. The Nile River basin is home to more than a third of Africa's 850 million people. It has experienced high population growth rates and the population of the basin is expected to double between 1995 and 2025. Virtually all population projections show continuing growth, which in turn will increase demand for water resources.

The primary water uses in the basin are water supply and energy generation. Egypt and the Sudan are the two major users of this river (18.5 and 55.5 billion cubic meters per year, respectively), while Ethiopia is the primary contributor to the bulk of the runoff that drives water resources availability in the basin. This imbalance in the primary producers and consumers of the basin's water resources makes the Nile River the international river system with the greatest potential to precipitate major armed conflict. The potential effects of climate change on the basin have received little attention though it is becoming increasingly obvious that the water resources of the basin are susceptible to climate change. In view of the

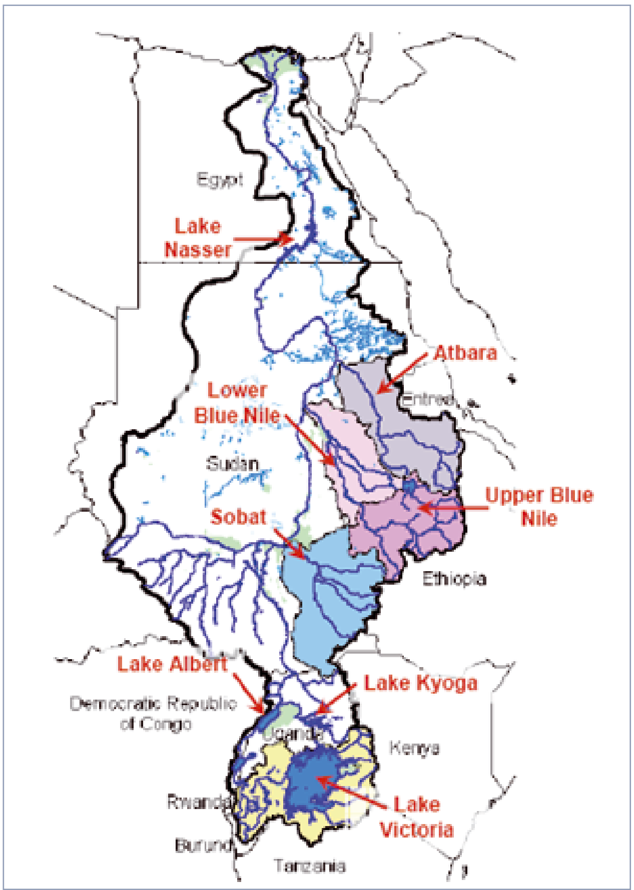


Figure 14.4: The Nile Basin (Source: Tidwell, 2006)

importance of the Basin and the potential threats from climate change, effective climate change impact assessments have become imperative to plan and implement effective adaptation policies in the basin.

4.2 Projected Climate

Climate models project temperature increases between 2 and 5 ° C by 2080 in the Basin. Precipitation projections vary widely across the Basin, ranging from a decline of about 38 percent to an increase of about 42 percent. In general, most models project increases in winter (DJF) precipitation for the region around Lake Victoria early in the 21st century, and summer (JJA) precipitation increases for eastern Africa, around the Blue Nile region throughout the 21st century (Tidwell, 2006). The timing and magnitude of changes in temperature and precipitation are critical to the hydrologic response of the Nile basin. Overall, there is a general agreement across models that the major sub-basins of the Nile River will generally experience decreases in watershed runoff. Simulated changes in runoff ranges from a decline of about 9 percent to an increase of about 15 percent for the Blue Nile and a decline of about 9 percent to an increase of about 12 percent for Lake Victoria (Tidwell, 2006).

4.3 Projected Impacts of Climate Change

This case study reviews the impacts of climate change on water availability, energy and river flow / lake levels in selected parts of the Nile basin. The review considers two scenarios, maintaining the present level of development into the future (baseline scenario), and a full basin-wide development (future scenario) and draws extensively from Tidwell (2006).

Based on the baseline scenario, climate change impacts on the main Nile are projected to include significantly reduced river flow, decreased energy generation, and water supply deficits. Detailed assessments of the responses of water resources to climate change in the Basin indicate that water supply deficits will emerge by 2030 and continue to grow in frequency and magnitude by 2080. By 2030, Egypt's water supply is projected to fall short of demand in almost all years, with an annual deficit of about 90 percent. However, under the future scenario where full basin-wide development is implemented, the frequency of annual deficits is reduced from more than 90 percent to approximately 50 percent by 2030. By 2080, the effect of basin development translates into an average deficit reduction of 5 billion cubic metres (bcm).

The baseline scenario projects appreciable decreases in energy generation by the 2030s in the Nile basin. The projected energy losses range from about 37 percent for Lake Victoria and about 30 percent for Egypt. By the 2080s the corresponding average losses will grow to 61 percent and 48 percent. Basin-wide, the average 2030 energy reductions will translate into about 9,224 GWH and the 2080 reduction amounts to about 21,000 GWH (Tidwell, 2006). Under the future scenario, a significant increase in hydropower generation is projected. By 2080 hydropower generation in the Equatorial Lakes could see a four-fold increase and Ethiopia/Sudan could witness a 21-fold increase. On the contrary, Egypt will likely experience energy reduction of up to 40 percent, amounting to about 5100 GWH. This confirms the result of previous research that the Nile is among the most susceptible rivers to climate change in terms of its potential for hydropower production.

In terms of water flow, the baseline scenario projects a 42 percent reduction in the annual outflow from the Equatorial Lakes by 2030. By 2080 the flows could be reduced by 67 percent. The scenario also projects a steady decline in storage in Lake Victoria and will stabilize by 2080s near the historical lake minimum. The High Aswan Dam will likely decline more rapidly and reach the lower reservoir limit near 2030. Reduced river flows and storage could lead to annual water supply deficits at Aswan of 5 bcm by 2030 and 13.7 bcm by 2080 (Tidwell, 2006). The future scenario projects that average annual flows from the equatorial lakes will remain unaffected, the Blue Nile, on the other hand, will likely lose 1 bcm per year due to evaporative losses over multiple reservoirs. Under the future scenario, there are improved opportunities for more adaptable reservoir management which could ultimately lead to reservoir levels remaining high for a longer period before the climate change effects begin to deplete water stores.

4.4 Implications for Water Resource Management & Sustainable Development of the Nile River Basin

Since water resources are inextricably linked with climate, the threats of climate change raises serious concerns regarding implications for water resources and regional development in a generally water-deficit continent such as Africa. Efforts to provide adequate water resources in the Nile river basin will confront several challenges over the next century, including population pressure and resulting land use changes, with potential hydro-ecological consequences. This will be compounded by weak institutional capacity to address the challenges.

Extreme climatic events such as droughts and floods will make addressing the pressing issue of water resources management in the Nile basin more complex. Future changes and uncertainties in the allocation of Nile water resources will have significant effects on local and regional economies, agricultural production, energy availability, and environmental quality. The majority of the population in the Nile Basin depends on agriculture for their livelihoods. Declining water availability will directly translate to reduced agricultural yields in the absence of better water management practices. Declining agricultural yields, besides making it more difficult to achieve the Millennium Development Goal of halving hunger by 2015, will also result in loss of livelihoods among the rural population as farming may no longer be seen as profitable business. The loss of livelihoods will further fuel rural-urban migration, with the attendant problems of over-population and slum establishments in the urban centres. These migrants in most cases will settle in marginal areas in the urban centres, areas that are at the greatest risk of the impacts of climate change through floods and disease epidemics.

Climate change will directly impact on water and energy infrastructures in the Basins. As already noted, declining water levels could lead to reduced energy production, which will consequently economic development and the quest for industrialization. Floods on the other hand will destroy existing energy and transportation infrastructure with consequent reduction in GDPs of riparian countries. The floods in Mozambique in 2000 and 2001 resulted in a reduction of about 5 percent of the GDP of this already impoverished country. Financial resources that could have been allocated for developmental projects were diverted to reconstruction of damaged facilities. Loss of land and homes during floods has created environmental refugees with the potential for the precipitation of conflicts, particularly in transboundary river basins.

From the foregoing, it is obvious that water resource planning based on the concept of a stationary climate is inadequate for sustainable water resources management of the Nile Basin. In addition to natural variability, which is incorporated in existing water planning methods, new water projects will have to deal with uncertainty associated with population growth and trends in climate change. Water resources planning studies for the Nile Basin will need to incorporate ongoing global climate change and uncertainties in the signature of future climate change.

While the concept of Integrated Water Resources Management has been around for a while in the continent, it is never really mainstreamed into national development policies and plans. Water resources issues cut across several government ministries and departments but the present structure of most government ministries do not allow for cross ministerial integration. Budgets and activities are siloed such that one Ministry or government agency that has responsibility over some aspects of water resources rarely communicates with another that also has responsibility for other aspects of water resources development and use, even within the same basin. The uncertainty in climate change predictions (particularly rainfall patterns in the Nile basin) and the complexity of water management issues facing basin water users will place a premium on more integrative approaches to dealing with water supply and demand changes in the basin.

5. Managing Climate Change in Africa's Transboundary River Basins

5.1 Mitigation and Adaptation

The United Nations Framework Convention on Climate Change (UNFCCC) identifies two major strategies in dealing with climate change: mitigation and adaptation. Mitigation involves the reduction of the accumulation of greenhouse gases in the atmosphere, while adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, 2001). Considering the relatively low contribution by Africa to the global accumulation of greenhouse gases in the atmosphere, and the fact that the continent will bear a disproportionate impact of global warming, adaptation becomes an urgent imperative in the continent. This paper will therefore place more emphasis on adaptation. However, because some mitigation strategies that could be applicable in the river basins also have co-benefits, efforts will be made to flag such.

Considering that much of the population in the Nile Basin depends on agriculture (including fisheries and forestry), which contributes about 30 percent of the total greenhouse gases, there are opportunities to reduce greenhouse gas from agriculture. At the minimum, such practices could generate substantial financial resources from the carbon market to the region when such agricultural practices that mitigate carbon are included in the Clean Development Mechanism of a post-2012 climate regime currently under negotiations. It is therefore important that governments and major stakeholders in the Basin begin to explore ways by which they can benefit from the global carbon market. In addition, mitigation and adaptation should no longer be viewed as two separate silos for addressing climate change. It is important to begin to think of practices that have co-benefits that contribute to reducing global greenhouse gas emissions, while also delivering adaptation benefits. For example, agroforestry practices can sequester carbon and at the same time can enhance the incomes of local farmers, while efficiently reducing nitrogen fertilizer use can improve water quality and reduce nitrous emissions.

Addressing adaptation issues in Africa's transboundary river basins will largely involve the generation and utilization of useable information to design effective decision tools for adaptation. Many of the institutions that are mandated to address climate change in Africa have very weak capacities. It is important to strengthen the capacities of these institutions to be able to generate the type of information that can be used for adaptation planning. Potential end-users will also have to be capacitated to be able to use the information correctly. As mentioned earlier in the paper, many of the River Basins do not have functional treaties to guide the use of water among the riparian countries. Where such treaties exist, many of them are outdated and were negotiated when climate change was not such a major threat. It is imperative that many of these treaties will have to be renegotiated to include strategies to address contemporary problems such as climate change.

The vulnerability within the river basins is not solely driven by climate change. Effective adaptation must also address pre-disaster vulnerabilities. Africa's water and energy infrastructure need to be upgraded. As mentioned earlier, only about 4 percent of Africa's water resources are currently exploited and significantly increasing this would go a long way to reduce vulnerability within the river basins.

Adaptation is not new in many local communities within the river basins as many local populations have been coping over the years with threats of climate variability. It is important to understand these practices and work with these local people to strengthen and improve on these practices where necessary. Many inappropriate and unsustainable adaptation technologies have been imported into the continent, particularly in the water sector. There is the need to invest more in research and development in the continent to develop more appropriate and useable adaptation technologies that will incorporate indigenous knowledge systems.

However, it is also important to recognize that there are maladatations and limits to adaptation. Poorly designed and implemented adaptation strategies can result in maladaptation. This is where adaptive responses result in unintended, adverse, secondary consequences that outweigh the benefits of undertaking the strategy. An adaptive response that is made without consideration for interdependent systems may, inadvertently, increase risks to other systems that are sensitive to climate change. However, even when a comprehensive approach is taken to the development of strategies for adapting to climate-induced effects, one must account for potential non-climate related side effects of the adaptive strategies to avoid maladaptation. For instance, improving water use through the construction of dams in river basins could create suitable habitats for vector diseases that can have unintended health consequences in the area.

The social acceptability of a particular adaptive response may depend upon who in society will benefit from the adaptation policy and who will lose. There are also numerous examples where specific adaptations impose adverse social externalities (all adaptation is not always good for everyone). For instance, the building of a dam for irrigation to improve agricultural yield has created suitable habitats for disease vectors. There are also instances where adaptations to moderate risks actually enhance vulnerability to larger events.

There are also limits to adaptation. The most visible limit is finance. Current estimates of costs are tentative and depend on the climate change scenario, and how ambitious the adaptation regimes are expected to be. However, some studies have placed the estimates of the total cost of adaptation in Africa at about USD2 – 10 billion each year, besides normal overseas development assistance (UNDP, 2007). Besides finance, other limits are perhaps even more critical; even if we had all the money the world we would still not guarantee complete adaptation. There are systemic limits to adaptation where some ecosystem species, human systems and cultures might be lost in the process of adapting. The higher the rate and/or magnitude of climate change, the more the systems that will be "adapted out of existence". There are also informational limits. The climate variables and spatial scales with the most relevance for adaptation decisions in the water and agricultural sector are generally the ones projected with the least certainty (e.g. precipitation, extremes, weather within the climate, local scale events, etc). Understanding the limits to adaptation will enable us think of more integrated strategies to reduce the impacts of climate change.

6. Conclusion

Efforts to reduce Africa's exposure and sensitivity to climate variability have to begin with analysis of recent events to identify barriers to their effective management. Success in this endeavour will be closely related to scientific and social capacity to anticipate climatic hazards, deliver effective support when they occur, and learn from these experiences. Improving capacity to do this in Africa is a pre-requisite for successful adaptation to climate change.

Adaptation to climate change should address both the short-term climate variability and the long-term climate change.

References

Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman, R. Tabo and P. Yanda (2007). Africa, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge. Pp. 433-467.

Christensen, J. H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R. K. Kiolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C. G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton (2007). Regional climate projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (ed. by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Christie, F., and J. Hanlon (2001). Mozambique and the Great Flood of 2000, James Currey, Oxford, 176 pp.

Conway, D. (2005). From headwater tributaries to international river: Observing and adapting to climate variability and change in the Nile basin. Global Environmental Change-Human and Policy Dimensions 15(2), 99-114.

Dai, A., P.J. Lamb, K.E. Trenberth, M. Hulme, P.D. Jones and P. Xie (2004). The recent Sahel drought is real. International Journal of Climatology, 24, 1323-1331.

de Wit, M. and J. Stankiewicz (2006). Changes in surface water supply across Africa with predicted climate change. Science 311(5769), 1917-1921.

Goulden, M., D. Conway and A. Persechino (2008). Adaptation to climate change in international river basins in Africa: a review Tyndall Centre for Climate Change Research Working Paper 127.

Hellmuth, M.E., A. Moorhead, M.C. Thomson, and J. Williams, (eds) (2007). Climate risk management in Africa: Learning from practice. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA.

Hulme, M., R. Doherty, T. Ngara, M. New and D. Lister (2001). African Climate Change: 1900-2100. Climate Research, 17: 145-168.

IPCC (2001): Climate Change 2001. The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, 881 pp.

L'Hôte, Y., G. Mahé, B. Some and J. P. Triboulet (2002). Analysis of a Sahelian annual rainfall index from 1896 to 2000; the drought continues. Hydrological Science, 47 (4), 563-572.

Li, K.Y., M.T. Coe, and N. Ramankutty (2005). An investigation of hydrological variability in West Africa using land surface models. Journal of Climate, 18, 3173-3188.

Milly, P. C. D., K. A. Dunne and A. V. Vecchia (2005). Global pattern of trends in streamflow and water availability in a changing climate. Nature 438(7066), 347-350.

Nemec, J., and J. Schaake (1982). Sensitivity of water resource systems to climate variation. Hydrological Sciences Journal, 27(3), 327-343.

Niasse, M. (2005). Climate-induced water conflict risks in West Africa: recognizing and coping with increasing climate impacts on shared watercourses, Workshop of Human Security and Climate Change, 21–23 June, Oslo, Norway

Odada, E.O., D.O. Olago, K. Kulindwa, M. Ntiba and S. Wandiga (2004). Mitigation of environmental problems in Lake Victoria, East Africa: Causal Chain and Policy Option Analysis. Ambio, 33, 13-23.

Saji, N.H., B.N. Boswami, P.N. Vinayachandran, and T. Yamagata (1999): A dipole made in the Tropical Indian Ocean. Nature, 401, 360-363.

Savenije, H. H. G. (1996). Does moisture feedback affect rainfall significantly? Physics and Chemistry of the Earth, 20(56), 507-513.

Tidwell, A. C. (2006). Assessing the Impacts of Climate Change on River Basin Management: A New Method with Application to the Nile River, Unpublished Ph.D. Thesis, Georgia Institute of Technology, U.S.A.

United Nations Economic Commission for Africa (2000). Transboundary River/Lake Basin Water Development in Africa: Prospects, Problems, and Achievements. United Nations Economic Commission for Africa, December 2000,

UNDP (2007). Human Development Report 2007-2008, New York

van Jaarsveld, A.S., and S.L. Chown (2001). Climate change and its impacts in South Africa. TRENDS in Ecology & Evolution, 16(1), 13-14.

Webster, P.J., A.M. Moore, J.P. Loschnigg, and R.R. Lebden (1999). Coupled Ocean-Atmospheres Dynamics in the Indian Ocean during 1997-98. Nature, 401, 356-360.

Wolf, A. T., J. A. Natharius, J. J. Danielson, B. S. Ward and J. K. Pender (1999). International River Basins of the World. International Journal of Water Resources Development 15(4), 387-427.

Annex

Contents

The Kampala Statement

Groundwater and Climate in Africa

Noting that the first conference to discuss the impacts of development and climate change on groundwater resources, Groundwater and Climate in Africa, held in Kampala, Uganda from 24-27 June 2008 was attended by more than 300 water and climate scientists, water managers and policy makers from 23 countries in Africa and 14 countries from the rest of the world; and that the role of groundwater in improving livelihoods in Africa under conditions of rapid development and climate change is poorly understood; we, the participants, make the following observations and recommendations:

1. Recognising that groundwater resources in Africa are broadly distributed, of generally good quality and resilient to climate variability including extreme climate events; that rainfall and freshwater from rivers and lakes will become more variable and thus less reliable as a result of climate change; that groundwater is the daily source of drinking water for more than 75% of the population across Africa; and that rapid population growth and economic development will place considerable reliance upon groundwater in Africa to meet the Millennium Development Goal of halving the number of people without access to safe water and sanitation by 2015; we stress that dependence upon groundwater in Africa to meet domestic, agricultural and industrial water demands will intensify substantially over the next few decades and call upon the international community to support the African Groundwater Commission (AGWC) and allied initiatives for coordinating research and advisory activities related to African groundwater.

2. Being aware that, on a continental scale, renewable groundwater resources in Africa are underutilised and that groundwater can play a pivotal role in helping African farmers both increase food production and overcome the threat to food security posed by more variable rainfall as a result of climate change; we call upon African governments and donor agencies to support specific policies, research and development cooperation to overcome key obstacles such as the high costs of well construction and limited understanding of groundwater resources that currently restrict development of groundwater for irrigation in many parts of Africa.

3. Recognising that major gaps exist in our knowledge of groundwater resources in Africa and that considerable uncertainty persists regarding the impact of climate change on groundwater resources and groundwater-dependent ecosystems in Africa; that demand for expertise in hydrogeology and climatology will rise with the inevitable increase in groundwater use in Africa; and that there is a need for African groundwater scientists, managers and policy makers to determine best practices and reduce inequities in capacity; we call for major investments in (1) programmes of applied, interdisciplinary research in groundwater and climate, (2) training and capacity building in hydrogeology, climatology and allied fields in water policy and management, and (3) the development of national and regional institutions to assess climate change impacts on water resources including the expansion in opportunities for information exchanges among decision makers, managers and scientists.

4) Recognising that sustainable use of renewable groundwater resources depends upon the quantity and quality of groundwater recharge; that substantial inter-annual variability exists in groundwater recharge in Africa and long lag times can occur between recharge events and aquifer replenishment; that the development of effective water management policies and planning of sustainable water development require sustained and accurate monitoring of climate conditions and water resources; and that groundwater and surface water resources are hydraulically connected in many areas, we urge African governments (1) to support the initiation and expansion of climate and water monitoring activities, (2) to integrate groundwater into Water Resources Management Plans, and (3) to develop water policies at national and regional levels that strike a balance between renewable groundwater resources and demand for groundwater, and recognise both the role of groundwater storage and the importance of groundwater discharges to aquatic ecosystems and services they deliver.

5) Being aware that valuable data generated through the construction of groundwater-based water supplies, are often not recorded or lost; and that these data can dramatically improve understanding of groundwater resources and facilitate more effective and efficient development of groundwater in the future through techniques such as groundwater mapping currently practised in several African countries; we strongly advocate for the establishment and promotion of (1) policies to encourage and assist organisations involved in the development of groundwater to record and submit groundwater data; (2) electronic databases to facilitate the storage and retrieval of hydrological data; and (3) institutional frameworks to manage, share and use hydrological data.

6) Recognising that water users are the main beneficiaries of water services and the most affected by inadequate management of water resources, and that direct participation of water users in water resources management would (1) enable rapid expansion of monitoring networks; (2) facilitate implementation of regulatory frameworks to protect the quantity and quality of groundwater resources and (3) encourage the translation of scientific understanding into decision making and helping to align demand with the availability of groundwater, we call for a partnership between government, as developers, managers and regulators, and communities and other stakeholders including the private sector, as water users, in the monitoring and management of groundwater resources.

7. Recognising that understanding of the sustainability of intensive abstraction of groundwater for piped, town water supplies throughout Africa is very limited; that the capacity of shallow aquifers to contain faecal wastes and to supply safe water under increasing population densities in peri-urban and urban areas of Africa is unclear; that episodic deterioration in shallow groundwater quality from heavy rainfall events and the risk of epidemics of waterborne diseases are expected to increase as heavy rainfall events become more frequent as a result of climate change; and that prevention of groundwater contamination is less costly than remediation which is often neither feasible nor affordable; we strongly recommend that (1) intensive abstraction of groundwater be closely monitored by users and regulators; (2) sustainable groundwater development policies for town water supplies be knowledge based; and (3) clear guidelines and regulations be developed to protect the quality of groundwater resources including the promotion and improvement of sanitation facilities through increased funding, sharing of best practice guides, and adoption of research recommendations.

8. Noting that management of Africa's transboundary aquifers requires a regional approach involving technical cooperation and joint monitoring among nations; and that drivers for interstate cooperation are required in order to avoid overexploitation, pollution, inefficient abstraction strategies and disputes over groundwater resources; that large volumes of groundwater in arid and semi-arid regions of Africa receive very little recharge in relation to on-going and planned abstraction; we call for an urgent strengthening of institutional structures at continental (e.g. AGWC) and regional scales, and the development of legal and institutional frameworks to enable sound governance and equitable sharing of transboundary groundwater resources.

Conference Participants,
Groundwater & Climate in Africa
24-28 June 2008, Kampala, Uganda.

Source: www.gwclim.org

The 6th Petersberg Round Table on Transboundary Water Management in Africa

From agreements to investments – How to put measurable value to transboundary water management in Africa – Key Findings

The 6th Petersberg Round Table on Transboundary Water Management in Africa took place from September 24-26, 2007, at the Petersberg, near Bonn, Germany. This informal policy dialogue forum is part of the Petersberg Process and was convened by the German Federal Government, the African Ministers' Council on Water (AMCOW), the World Bank, the Global Environment Facility (GEF) and the UN Development Programme (UNDP). The event was a high-level informal policy dialogue in a retreat-like setting. It brought together around 70 decision-makers including ministers, experts from Africa, the international donor community, and various international organisations. During these days the participants had discussions in plenary sessions and smaller working groups, focussing on the challenges for TWM in Africa and the prerequisites for more investments in transboundary infrastructure and regional institutions in the African water sector.

The generation of benefits through TWM is a crucial element for political integration and economic development in the region. The delegates underlined that the goals and strategies set out in the **African Water Vision 2025** serve as a guide towards sustainable use of Africa's water resources. It was common understanding that much has been achieved in Africa so far but that, nevertheless, there was still much to be done to maximise and fairly share the socio-economic, political and environmental benefits through TWM! It became apparent in the different sessions that riparian states must significantly increase their political and financial commitment to the management of their transboundary water resources, e.g. mobilize significant new investments and establish sustainable financing mechanisms for regional water infrastructure. The discussions resulted in a consensus on priorities for TWM in Africa.

This paper summarises the key findings and serves to introduce the outcome of this 6th Petersberg Round Table to the current political process and the international debate through relevant fora such as, a.o., G8, AU Summit 2008, and World Water Forum 2009.

The AU Summit 2008 in particular could provide a good opportunity to raise the profile of water issues with African leaders.

Special thanks go to the facilitators of the event Stephen Maxwell Donkor (UNWater/Africa) and Anders Jägerskog (SIWI).

Key Findings

1) TWM in Africa is a key issue in the adaptation to climate change

- Climate change in Africa is a fact having a strong impact on Africa's water resources. Adaptation to this impact is of crucial importance for political and socio-economic stability and economic growth.
- There is a great need for adaptation strategies to be developed together with all partners on the basis of sub-regional future scenarios, including expected changes to the hydrological cycle and impact on agriculture and food security.
- Institutions at all levels must develop capacities to cope with climate change and extreme events. Transboundary cooperation on floods and droughts through a better exchange of information and know-how as well as early warning systems will have to increase significantly. External assistance may be required.
- Water management plans and the infrastructure development planning have to take into account possible changes in the future availability of surface- and groundwater resources while balancing multiple uses across sectors.
- The effects of climate change will increase the importance

of groundwater resources for future water and food security in the region.
- Intensified political dialogue and joint actions in the AMCOW-framework are needed on the effects of climate change and their implications for water management in Africa.
- AMCOW and regional institutions in TWM should develop capacities to better integrate information about climate change and climate variability into water resources policy, planning and management.

2) TWM in Africa needs extensive infrastructure development
- Massive infrastructure investments are needed and recommended to be effected within the framework of the African Water Vision 2025 and under the political umbrella of the AU and AMCOW. This should also take into account the water and sanitation MDGs.
- Capacities in Africa to store surface and groundwater must be significantly increased – taking into account the international sustainability standards set by WCD.
- A multi-purpose approach to water resources management (with ex ante analyses of environmental and social impact) is crucial for a sustainable management of transboundary waters and a prerequisite to delivering benefits to multiple sectors and stakeholders – by bridging traditionally competing sectors.
- Infrastructure development in riparian states needs to take a more conscious transboundary perspective. Riparian states should enter into a policy and technical level dialogue to support the establishment of fair and effective benefit (and risk) sharing mechanisms and exchange lessons learnt.
- The provision of additional financial resources for water infrastructure must become a priority issue for African governments and international donors.

3) TWM in Africa needs a strong political will at highest national level
- Good water management across borders requires more political support and involvement as well as strong commitment by the riparian states at the highest national level, including commitments to cooperation among all sectors concerned, like water, agriculture, finance and energy.
- The potential benefits, responsibilities, risks and costs resulting from TWM must be identified by the riparians at all levels and sectors concerned and for all interest groups in each particular basin.
- To achieve this, relevant water issues have to be promoted and ranked high on the national political agendas.
- The European Union and the African Union should make water management a priority in their strategic partnership.

4) TWM in Africa is far more effective if civil society is involved
- Participation of civil society improves the quality of decisions and is crucial for both credibility and public support. Participation has to move from rhetoric to real participation in decision-making-processes.
- Parliamentary dialogues and the participation of communities in the work of regional institutions such as R/LBOs are starting in Africa and need further strengthening.

5) TWM in Africa needs innovative financing mechanisms and additional resources
- Many financing mechanisms are in place. Nevertheless, there is a wide financing gap, and a significant increase of both internal financing and ODA is required. This should include additional innovative financing mechanisms, the development of domestic capital markets, and targeted capacity development for project development and implementation.
- Different financing mechanisms are developed separately and supported by different partners. Harmonisation strategies for the development of those mechanisms are important.
- Regional institutions (such as the AfDB and AWF) are adequate players and instruments for effective resource mobilisation in the region, and should be supported by donors to build up the capacity of these African institutions to meet Africa's needs.

6) TWM in Africa requires strong regional institutions for good water governance
- The regional institutional set-up is still young but shows an encouraging state of institutional development – e.g. the R/LBOs at basin level, RECs at regional level, and continent-wide AMCOW, ANBO and AU. While sufficient capacity, financing and good management are necessary, their success depends significantly on political support in the region.
- For these institutions to be effective, further strengthening through institutional and human capacity development is needed and should include AMCOW which plays a crucial role in bringing the agenda forward. Regional political integration has to be expanded and intensified.
- As a prerequisite for good water governance, monitoring systems as well as the collection, harmonization and exchange of uncontested and freely accessible data is crucial. These mechanisms must be set up with the support of both member states and development partners.
- The mix of instruments between dialogue processes and concrete investment must become more balanced, and donor commitment in the field better coordinated along the lines of the Paris Agenda.

The Authors

Datius RUTASHOBYA holds MSc and BSc degrees and a Postgraduate Diploma in Hydrological Engineering and is a Tanzanian specialist in hydrology and water resources. He is currently Scientific Officer in the Climate and Water Department of World Meteorological Organization (WMO) in Geneva, Switzerland. He previously worked with UNESCO's Department of Water Sciences in Paris. For 28 years, he worked with the Water sector in Tanzania. He is a past President and Vice-President of WMO's Commission for Hydrology and Director for Africa for the International Rainwater Catchment Systems Association (IRCSA). He has chaired many international forums, undertaken various consultancy works and written publications covering aspects in hydrology, water resources, water harvesting and climate.

Roland SCHULZE, who holds a PhD degrees from the University of Natal as well as being a PH (USA) and a Fellow of the Royal Society of South Africa, is currently a Senior Research Associate in the School of Bioresources Engineering and Environmental Hydrology at the University of KwaZulu-Natal, from where he recently retired as Professor of Hydrology. Originally a hydrological model developer, his main focus now is on climate change related issues on the water and agricultural sectors and on hydro-climatic mapping. He is author of over 350 publications and has wide international lecturing and collaborative research experience.

Madiodio NIASSE holds a Doctorate in Environmental Sciences and a MA in Geography, both degrees from the University of Dakar, Senegal. At the time of writing his contribution to this publication, Dr. Niasse was Research Director with the French Institute for Development Research (IRD) in Montpellier, France. He has recently been appointed Director of the International Land Coalition (ILC) hosted by IFAD in Rome, Italy, where he is now based. Dr. Niasse is the outgoing chairman of the West Africa Water Partnership (GWP/WA). He is also Adjunct Research Scientist with the Bureau for Applied Research in Anthropology (BARA), University of Arizona, USA. He has published extensively on water and river basin management, climate change adaptation, land tenure, conflict risks management, and related topics.

Boaventura Chongo CUAMBA holds a PhD degree in Energy Physics (1996) from the Northumbria University, in the UK, and a Dipl. Phys. degree in Solid State Physics (1985) from the University of Jena in Germany. His B.Sc. degree is from the Eduardo Mondlane University in Mozambique, in 1981. Presently he is coordinator of the Energy, Environment and Climate Research Group, an interdisciplinary research unit based at the Faculty of Sciences of the Eduardo Mondlane University, and Associate Professor at the same Faculty. He has participated in different research activities in the area of energy and climate change, with focus on renewable energies, adaptation and mitigation activities to climate change and variability.

Genito MAURE holds a MSc in atmospheric Science and is currently involved in a PhD work on the modeled effects of biomass burning aerosol on the southern Africa's climate at the University of Cape Town, South Africa. Along with this, he is also involved in several activities ranging from prediction of extreme climate events through air pollution, with the major role in analysis of climate variability and extremes. During the last few years he's been involved in the preparation of the II National Communication of Mozambique to the UNFCCC as well as in the Country Project of the Republic of Angola for their I National Communication.

Hillary MASUNDIRE has a PhD in Freshwater Ecology - he studied in Zimbabwe and Sweden. He has worked as a Research Fellow at the University of Zimbabwe's Lake Kariba Research Station. Since 1994, he has been on the academic staff of the University of Botswana, teaching Freshwater Ecology, Wetlands Ecology & Management and Biostastics. He is involved in research on waste management, environmental flows and ecosystem science. He participated in the development of the World Vision Water for Nature - the precursor to the World Water Forum, the World Commission on Dams and the Millennium Ecosystem Assessment projects. For 8 years to 2008, he chaired the IUCN Commission on Ecosystem Management in which capacity he led several initiatives on operationalizing the ecosystem approach. In this regard, he has worked closely with the UN CBD, UN CCD, UNEP, UNDP and various regional bodies in Africa and beyond. He co-authored a book on „Ecosystems, Livelihoods and Disasters: an integrated approach to disaster management“ following the Indian Ocean tsunami of 2004. He has just completed a guideline for applying the ecosystem approach in District Landuse Planning for the Government of Botswana.

Enoch M. DLAMINI holds a Masters Degree in Civil Engineering from the University of Alberta in Canada. He recently left the Komati Basin Water Authority (KOBWA) in August 1998 where he was the Manager responsible for Water Management. He was instrumenetal in the resettlement of people affected by Maguga Dam. Prior to that he was the Project Manager for the DFID Poverty Alleviation Programme in Swaziland. He also worked for more than ten years for the Government of Swaziland in the Water Resources Department of the Minsitry of Natural Resources and Energy where he was a Planning Engineer. During this time he was involved in the negotiation for the Treaty on the Development and Utilization o fthe Water Resources of the Komati River Basin between South Africa and Swaziland. He is now with the SADC Secretariate in the Water Division where he is the Programme Manager for the Regional Strategic Water Infrastructure Programme.

Michael James TUMBARE holds PhD, MBA and BSc(Eng)(Hons) degrees. Professionally, he is a Fellow of the Institute of Civil Engineers (UK), a Fellow of the Zimbabwe Academy of Sciences, a Fellow of the Engineering Institute of Zambia, a Fellow of the Zimbabwe Institute of Engineers and an Associate of the Chartered Institute of Arbitrators (UK). He is currently the Chief Executive of the Zambezi River Authority, a binational Organisation which owns, operates, maintains and monitors the Kariba Dam Complex and manages the hydrology and environment of the Lake Kariba‘s catchment. He has published over thirty papers internationally.

Amos Enoch MAJULE holds BSc, PhD degrees and is a Senior Research Fellow at the Institute of Resource Assessment (IRA) of the University of Dar es Salaam in Tanzania in the field of Agriculture (Soil and water management). Dr Majule joined IRA in 2000 after working with the Ministry of Agriculture, Food Security and Cooperative. Over the last four years, he has been coordinating a section on Agricultural Food Security and Poverty Alleviation at IRA. Dr Majule served as a steering committee member and vice chair of the Nile Basin Discourse Forum (NBD) for a period of three years ending in 2008. He is now a Regional Technical Committee member for Global Water Partnership-South Africa (GWP-SA). He is an accomplished writer, and has published extensively in the area of agricultural soil science. He is currently involved in an number of climate change research particularly on adaptations with agricultural innovation systems in Tanzania and Malawi through Climate Change Adaptation in Africa fund ed by IDRC and DFID

Peter JOHNSTON recently completed his PhD in communicating and assessing the usefulness of seasonal forecasts to maize farmers in South Africa. He has managed and participated in various projects involving climate information, vulnerability and adaptation to climate change in Southern Africa. He is based at the Climate Systems Analysis Group at the University of Cape Town. His interests lie in communication of climate change and variability information to stakeholders, especially in the agricultural and water sectors.

Gina ZIERVOGEL holds BSc and DPhil degrees and is a lecturer in the Department of Environmental and Geographical Science at the University of Cape Town, South Africa. Her research, linked to the University and the Stockholm Environment Institute has been in the field of climate change adaptation with a particular focus on how climate information is currently used and disseminated in southern Africa among low-income communities. Gina has been involved in the ACCCA project (Advancing capacity for climate change adaptation) where she has worked with project teams across Africa. In her latest visit to Malawi she worked with participatory film makers who were helping people in Mphunga village capture their story of the impact and response to floods in the village. She has also been involved in research in South Africa on improving access to climate information for water resource managers.

Audace NDAYIZEYE holds MSc and is a Burundian with a well-rounded and hands-on experience in energy, water resources and environment management acquired during the past 25 years working with Governments, regional and international institutions. Over the last ten years, he has been involved in climate change related issues such as the reviews of National Communications and GHG inventories and trainings in greenhouse gas mitigation assessment for national experts from NA1 countries involved in the preparation of National Communication on Climate Change. In 2006 he joined Nile Basin Initiative (NBI) Secretariat as Executive Director for a term of two years that ended in August 2008. He is currently providing consultancy support to NBI in strategic planning and management.

F.C. Oweyegha-Afunaduula completed a B.Sc degree in Zoology and Botany with Development Studies at the University of Dar-es-Salaam, Tanzania (1973-76). During 1980-82 he did an M.Sc in Biology of Conservation at the University of Nairobi, Kenya, subsequently becoming one of the three pioneering Ugandan graduates in this new field of learning. Between 1991-94, he was on a PhD programme on "Human-elephant interactions/conflicts in the Kibale Game Corridor, Uganda" at Makerere University. He was interested in socio-economic and socio-cultural aspects, which at the time had not been fully welcomed in the natural sciences and were poorly understood and dismissed as alien by natural scientists. He has lectured Environmental Science, Conservation Biology, Environmental Planning and Management and Ecology at Makerere University since 1991, where he has also been a Secretary General of the Academic Staff Association. His current interest is Interdisciplinarity and integrative science. Oweyegha-Afunaduula is the Chairman of the Nile Basin Discourse (NBD). He is also Chairman of the Uganda Nile Discourse Forum (UNDF) and Secretary General of the National Association of Professional Environmentalists (NAPE) in Uganda.

Ousmane S. DIALLO is engineer in water resources management and holds a M.Sc. in Environmental Systems Analysis and Monitoring. With a long and distinguished career in his native Burkina Faso and abroad (West Africa), he prepared and launched the GEF Project for the Niger Basin and the shared vision process. Prior to joining NBA, he was Managing Director of Water and Chairman of the Board of Administrators of Water Supply Company and Coordinator of the process for IWRM in West Africa. He is currently Coordinator of the Water Programme at the Sahara and Sahel Observatory (OSS) in Tunis. He is a member of the Task force of African Ground Water Commission AGWC/AMCOW, GWP West Africa and the AWC.

Anthony NYONG is a Principal Climate Change Expert at the African Development Bank. Before joining the Bank, he was a senior specialist for the program on climate change adaptation in Africa of the International Development Research Centre, based in Nairobi. He served as a professor of global environmental change and the Director of the Centre for Environmental Resources and Hazards Research at the University of Jos, Nigeria. He was a coordinating lead author for the chapter on Africa in the Intergovernmental Panel on Climate Change's Fourth Assessment Report, and served on the panel's task group on data and scenario support for impact and climate analysis. In addition, he has been a member of the scientific and technical advisory panel of the United Nations Global Environment Facility, of an expert panel on technologies for adaptation to climate change of the United Nations Framework Convention on Climate Change, of the science advisory committee of the Global Environmental Change and Food Systems, and of the pan-African committee for START (the global change System for Analysis, Research, and Training). He has served as a senior visiting scientist at the Stockholm Environment Institute and the University of Oxford. Anthony Nyong holds PhD degree from McMaster University, Canada and is a Fellow of the Royal Geographical Society. He has published widely on global environmental change, particularly climate change.

Thomas PETERMANN is a Senior Programme Manager at InWEnt responsible for capacity building programs in the fields of natural resources management, water development, nature conservation and land use planning. He joined InWEnt in 1994 and has since then conducted policy dialogue, professional training and regional networking with programs in Sub-Sahara Africa, the Near East, Southeast Asia, Central Asia, Southern Caucasus and the Andes. He is also Theme Manager "Natural Resources, Water and Climate Change Adaptation" to coordinate all related InWEnt programmes in the context of the German development cooperation. His professional career started in 1977 with engineering consulting firms engaged worldwide in planning and implementing irrigation and agricultural development projects, water resources development, land reclamation and drainage, and erosion control projects. He holds PhD degree from the Technical University of Berlin in Land and Water Development, after completing his studies in soils, landscape ecology, hydrology, and land and water management. He is a Fellow of the German Water Association, Soil Science Society of Germany, German EIA-Association and member of the IUCN World Commission on Protected Areas. His interest in climate issues emerged during the national service at an weather service station of the airforce.

InWEnt - River Basin Dialogue Programme

The Division **"Natural Resources and Biodiversity"** is part of the InWEnt Department 5 "Environment, Natural Resources and Food". Based at the International Training Centre Zschortau (near Leipzig), we focus on natural resources policy, regional management, integrated land and water management, water resources management, ecosystems management, biodiversity conservation, and climate change adaptation. We are engaged in capacity building programmes through dialogue, training, networking and strategic human resources development in Africa, the Near East, Latin America, Asia, and Southeast Europe as well as in Germany.

The InWEnt Programme "River Basin Dialogue" (RBD) commenced in 2008 on behalf of the BMZ as part of the German international cooperation programme "Transboundary Water Management in Africa" to help promote cooperation and exchange of knowledge among river basins and contribute to capacity building in transboundary water policy formulation and governance in Africa.

RBD aims "to enable decision makers and managers of shared watercourse institutions (SWCI) to develop institutional processes and implement mechanism at regional, national and local levels towards collaborative and sustainable integrated water resources management (IWRM)". Three RBD components are addressing key elements of effectively functioning SWCI:

1. Effective Multistakeholder participation in SWCI: Develop multi-stakeholder participation strategies and initiate implementation mechanism to facilitate dialogue and consensus building between user groups in managing river basins sustainably.
2. Sustainable Major Water Infrastructure Development: Promote social and environmental standards and initiate effective decision-making and coordinating mechanism for balancing environmental, social and economic aspects in major water infrastructure development in shared water courses.
3. Enhancing IWRM competence: Improve capacity to adapt integrated water resources management regimes in SWCI under conditions of climate change and potential conflicts over increasing water shortages.

Department Environment, Natural Resources and Food
Division Natural Resources and Biodiversity
Thomas Petermann, Senior Programme Manager
Lindenstraße 41 (Zschortau)
04519 Rackwitz, Germany
Phone +49 8157 938 202
Fax +49 8157 938 777
thomas.petermann@inwent.org
Programme webpage: www.gc21.inwent.org/nrm-net

InWEnt - Capacity Building International, Germany

InWEnt – Qualified to Shape the Future

InWEnt – Capacity Building International, Germany, is a non-profit organisation with worldwide operations dedicated to human resource development, advanced training and dialogue. Our capacity building programmes are directed at experts and executives from politics, administration, the business community and civil society.

Our Programmes

60 percent of all our programmes are implemented at the request of the Federal Ministry for Economic Cooperation and Development (BMZ). In addition, we conduct programmes for other German federal ministries and international organisations. We are also working in cooperation with the German business sector in public private partnership projects that can be designed to incorporate economic, social and environmental goals.

The programmes for people from developing, transition and industrialised countries are tailored to meet the specific needs of our partners. We offer practice-oriented advanced education and training, dialogue sessions, and e-Learning courses. After the training programmes, our participants continue their dialogue with each other and with InWEnt via active alumni networks.

By offering exchange programmes and arranging scholarship programmes, InWEnt also provides young people from Germany with the opportunity to gain professional experience abroad.

Our Offices

InWEnt gGmbH is headquartered in Bonn. In addition, InWEnt maintains 14 Regional Centres throughout the German Länder, providing convenient points of contact for all regions. Our foreign operations in Beijing, Cairo, Hanoi, Kiev, Lima, Managua, Manila, Moscow, New Delhi, Pretoria, São Paulo, and Dar es Salaam are usually affiliated with other organisations of German Development Cooperation.

InWEnt – Internationale Weiterbildung und Entwicklung gGmbH
Capacity Building International, Germany
Friedrich-Ebert-Allee 40
53113 Bonn
Phone +49 228 4460-0
Fax +49 228 4460-1766
www.inwent.org





InWEnt
Internationale Weiterbildung und Entwicklung gGmbH
Capacity Building International, Germany
Friedrich-Ebert-Allee 40
53113 Bonn
Fon +49 228 4460-0
Fax +49 228 4460-1766
www.inwent.org

with International Cooperation Partners