CLIMATE CHANGE, WATER, AND WETLANDS IN SOUTHERN AFRICA

A POSITION PAPER SUBMITTED TO THE INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE-REGIONAL OFFICE FOR AFRICA (IUCN-ROSA)

By

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TABLE OF CONTENTS

EXECUTIVE SUMMARY ..... **iv**

ABBREVIATIONS AND ACRONYMS ..... **vi**

1 INTRODUCTION **1**

1.1 Context of Paper ..... ***Error! Bookmark not defined.***

1.2 Organization of the Position Paper *1*

2. DISTRIBUTION, FUNCTIONS AND VALUES OF FRESHWATER ECOSYSTEMS IN SOUTHERN AFRICA **2**

2.1 Freshwater Wetlands in Southern Africa *2*

2.2 Current Water and Wetland Uses and Management *5*

2.3. Expected Future Use of Water and Wetland Resources *7*

3 LINKS BETWEEN CLIMATIC VARIABLES, HYDROLOGICAL REGIMES, AND STATE OF WETLANDS IN SOUTHERN AFRICA **8**

3.1 Climatic Characteristics *9*
3.1.1 Rainfall 9
3.1.2 Temperature 12
3.1.3 Evapo-transpiration 13
3.1.4 Additional Evidence that Changes may be Affecting Freshwater Ecosystems in Southern Africa 13

4 PROJECTED CLIMATE CHANGE AND IMPACTS IN THE REGION **14**

4.1 Predicted Rainfall *15*

4.2 Predicted Temperatures *15*

4.3 Predicted Evapo-transpiration *16*

4.4 Predicted Runoff and Hydrological Regimes *16*

4.5 Predicted Sea Level Rise *16*

4.6 Extreme Events and Water Quality *17*

4.7 Effects on Ecological and Socio-economic Systems *17*
4.7.1 Water Resources 17
4.7.2 Food Insecurity 19
4.7.3 Human Health 19
4.7.4 Impacts on Infrastructure 20

5. INSUFFICIENT STATE OF KNOWLEDGE OF CLIMATE CHANGE IMPACTS ON FRESHWATER ECOSYTEMS IN SOUTHERN AFRICA **20**

6 STRATEGIES FOR PREPAREDNESS AND ADAPTATION **23**

6.1 Planning for Water and Wetland Management *23*

6.2 Ecosystem-based Approach and Community-based Natural Resources Management *23*

6.3 Water-supply Options *25*

6.4 Policies and Legislation *26*

6.5 Insurance ... *26*

6.6 Early Warning and Disaster Preparedness ... *26*

7 MECHANISMS FOR PROMOTING AND FINANCING RESILIENCE OF WATER AND WETLANDS ... 28

8 CONCLUSION ... 28

9. REFERENCES ... 29

APPENDIX I: PROJECT PROPOSAL ... Error! Bookmark not defined.

EXECUTIVE SUMMARY

This paper presents the water and wetland situation in the southern African region and the sensitivity of these resources to changes in climate particularly in the light of the threat of climate change. The paper is intended to motivate dialogue among regional water/wetland stakeholders on possible measures the region can adopt to prepare and adapt to the predicted impacts of climate change.

Initially the importance of water and wetlands to development and maintaining of the ecological balance is highlighted. The many types of wetlands in the region of both natural and artificial origin are presented indicating their various socio-economic benefits to the water, power/energy, agriculture, tourism, transport, and fish sectors/industries.

To date there is little evidence of priority given to management of these wetlands as none of the southern African countries has a wetland policy yet. Another half of the countries have neither ratified the Ramsar Convention on wetlands nor have a water policy. Management of water and wetlands is not integrated and little focus has so far been given to wetlands management.

Among the various water consuming sectors, agriculture through irrigation is the largest and this is also the global trend. Whilst countries may aspire to allocate water for the environment, there are no reliable tools for accurately estimating water required to sustain forests, grasslands, wetlands and other ecosystems, and this is an area requiring further investigation.

Long-term data have signs that temperature has been slowly increasing above the long term means. What is evident in rainfall trends is that the frequency and severity of droughts and tropical storms causing floods have been increasing towards in recent times. Temperature, and flood levels measured in the last decade have exceeded any measured in more than 50 years. The higher temperature will increase water demand and evapotranspiration and erratic rainfall will create large uncertainties in forecast water supplies. Excluding the impact of climate change, the water demand estimated for 2020 based on population shows a 93% increase compared to 1995 consumption. Considering that some countries may have exhausted their national water resources by then in a normal demand situation, the challenge of meeting this demand is daunting in the light of the threat of climate change.

Impacts of climate change on water and wetland resources are expected to be worse than already experienced in the past with climatic variability. Southern Africa is predicted to be warmer and drier than even the severe droughts of 1991-1995. The likely impacts of climate change by the dawn of 2100 in southern Africa will include, a temperature increase of up to 4.7 °C; a reduction in rainfall of -2 to –25% and increased evapo-transpiration of up to 132% resulting in a reduced runoff of up to 50%.

The sea level in the region is also expected to rise up to 0.55m with consequences for salt water intrusion into groundwater, possible destruction to infrastructure like harbours and inundation of coastal areas.

A high frequency, with unpredictable occurrence and distribution, of extreme events such as severe rain storms, drought and severe winter spells have been forecast. Poor water quality will result from impacts of such extreme climatic events.

Climate Change impacts will also result in a number of socio-economic impacts. Basing on past cases of droughts and floods and GCM modelling of vulnerability of economic sectors in the region, the impacts of such predicted changes in climate on water availability and supply, food security, health and infrastructure are expected to be more severe. The goods and services of the wetlands will become limited and the negative impacts such as diseases will be enhanced.

The anticipated situation therefore calls for the water and wetlands stakeholders to put strategies to adapt and be prepared to deal with the impacts of climate change. Since climate change will occur anywhere, the regional effort should go into managing the available resources and the regional water and wetland stakeholders are being prompted to dialogue and come up with strategies in the following areas:-

- How to collate reliable data covering the whole region for water and wetland planning and decision making. Preparedness requires information on water supply (surface and groundwater), water demand and wetland resources. Consideration should be given to available relevant information and on-going data collection initiatives in designing surveys for additional data.

- How to integrate water and wetland management in an ecosystem approach and employ community based management of these resources.
- What water supply and demand options the region can adopt and how they can alleviate water shortage during climate change.
- Verifying effectiveness of existing policies and legislation on water and wetlands and how to incorporate relevant regional and international agreements and conventions.
- How to insure infrastructure and wetland goods and services against the threat of climate change and how to valuate goods and services for insurance purposes.
- Additional requirements for early warning and disaster preparedness.

Capacity building requirements focus on reliable assessment of impacts, adoption of new approaches, water/wetland resource management and strengthening disaster preparedness institutions to deal with anticipated large-scale disasters under climate change. A number of financing mechanisms for implementing the strategies have been proposed and the emphasis is placed on making the source local and sustainable with support from UNFCCC portfolios and the NEPAD initiative.

The opportunity for action should be sought in integrating strategies on some existing initiatives and learning through pilot projects. A project proposal has been developed that provides for a regional roundtable to dialogue on the preparedness for, and adaptation to impacts of climate change in the context of water and wetlands management. The proposal also provides for creation of an adaptation framework for water and wetland management under climate change.

ABBREVIATIONS AND ACRONYMS

AIDS	Acquired Immuno Deficiency Syndrome
CBD	Convention on Biodiversity
CBNRM	Community Based Natural Resources Management
CCC	Canadian Climate Centre
CCD	Convention to Combat Desertification
CO_2	Carbon dioxide
CSM	Climate System Model
DANCED	Danish Cooperation for Environment and Development
DCP	Data Collection Platform
DEAT	Department of Environment Affairs and Tourism of South Africa
DMC	Drought Monitoring Centre
EECG	Energy, Environment, Computer and Geophysical Applications
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization of the United Nations
GCM	General Circulation Model
GDP	Gross Domestic Product
GFDL	Geophysical Fluid Dynamics Laboratory
GISS	Goddard Institute of Space Sciences
HADCM	Hadley Climate Model
HYCOS	Hydrological Cycle Observing System
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
IUCN	International Union for the Conservation of Nature and Natural Resources (a.k.a World Conservation Union)
MCM	Million Cubic Metres
NCDC	National Climatic Data Center
NEPAD	New Partnership for Africa's Development
NGO	Non Governmental Organization
NORAD	Norwegian Aid for Development
OSU	Oregon State University
ROSA	Regional Office of Southern Africa
SA	South Africa
SADC	Southern African Development Community
SARDC	Southern African Research and Documentation Centre
SOE	State of Environment
SRES	Special Report on Emissions Scenario
UKHI	United Kingdom Meteorological Office High Resolution Model
UKMO	United Kingdom Model
UKTR	United Kingdom Meteorological Office Hardley Centre Transient Model
UNFCCC	United Nations Framework Convention on Climate Change
USD/US$	United States Dollars
WANI	Water and Nature Initiative
WGI	Working Group One
WGII	Working Group Two
WTC	Water Transfer Consultants of Namibia
WTO	World Trade Organization
WWF	World wildlife Fund
ZRA	Zambezi River Authority

1 INTRODUCTION

The IUCN's Water and Nature Initiative (WANI) programme seeks to initiate a regional dialogue on the likely effects of climate change on water and wetlands in order to inform stakeholders in Southern Africa of these interrelationships between these variables. The regional dialogue is needed for purposes of increasing the level of preparedness and adaptation to climate change in water and wetland resource policy and management because the Southern African region, comprising of the SADC countries[1] on the mainland are considered sensitive to climatic changes because they have, in the past, been negatively affected by episodes of climate variability. Among the resources sensitive to changes in climate are water and wetlands. These resources are indispensable for development; they play a major role in maintaining an ecological balance and provide other services and goods of tremendous importance to the region.

Studies by Magadza (1996) and Hulme et al. (1996) suggest that the likely impacts of climate change by the dawn of 2100 in Africa might include increases of 1.0° to 4.7 °C in temperature, reduced rainfall by -2 to –25%, increased evapo-transpiration up to 132%, and reduced runoff up to 50%. Management of water and wetland resources is, therefore, imperative for continued sustenance of the regional environment and economic activities.

Since the predicted impacts might be worse than those caused by climate variability in the past, the climate change phenomenon calls for even more effort to manage these resources than present. The unfolding national, regional and international initiatives on management of water and wetland resources may not face up to the anticipated challenge of climate change impacts because most of the region's economies are weak and hence vulnerable to environmental perturbations. This is the more reason stakeholders are being prompted to initiate dialogue and put in place measures to deal with the predicted potential impacts before they occur. The problem, however, is that while countries have been sensitised about the potential effects of climate change, there is currently a lack of regional dialogue on the steps needed to increase the level of preparedness and adaptation to climate change in water and wetland resource policy and management. The purpose of this paper, therefore, is to present compelling evidence of the likely threats to the region's freshwater ecosystems. To this end, the paper summarizes salient points that depict the interrelationships between water, wetlands, and climate change in order to initiate the much-needed dialogue. To facilitate the dialogue, the paper presents a project concept for a number of activities, one of which is a regional roundtable conference (Appendix I).

1.2 Organization of the Position Paper

In conformity with the Terms of Reference, the paper is divided into 6 sections, excluding Section 1, which is the Introduction, and hence it provides the rationale for dialogue on water, wetlands, and climate change. Additionally, this section describes the purpose of this position paper. Section 2 describes the distribution, functions and values of freshwater ecosystems. The importance of water and wetlands to development and maintaining of the ecological balance is also highlighted. The different types of wetlands in the region of both natural and artificial origin are presented thereby indicating their various socio-economic roles in sectors

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[1] Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe

such as energy, agriculture, tourism, transport, fisheries, and industries. Additionally, the section discusses current uses and management of water and wetland resources. The section then concludes with a description of challenges and expected future use of water and wetland resources in the region. Section 3 describes past climatic trends and socio-economic experiences, current regional climatic characteristics, and the projected changes in climate and their impacts in the region. Its principle purpose is to provide evidence linking climate variables (temperature, and precipitation trends), hydrological regimes (runoff and water levels in selected rivers, dams, or lakes) and state of wetlands in the past as well as in the present.

The purpose of section 4 is to address the projected impact of climate change, including those on temperature, precipitation, extreme events, runoff, water quality, groundwater conditions, and sea levels. Section 5 attempts to document current work in the region to address climate change impacts including vulnerability assessment, preparation of national communications, and policy development. Section 6 is a description of strategies for climate change preparedness and adaptation, as well as opportunities for water and wetland planning, implementation and management. Its major goal is to describe the range of technical and non-technical measures that currently exist, and hence they could be employed to avoid, minimize, or adapt to impacts of climatic variability on freshwater ecosystems. Lastly, the aim of section 6 is to address the extent to which climate risks are integrated into current water and wetland planning and management. Section 7 addresses the extent to which climate risks are integrated into current water and wetland planning and management. It also highlights the opportunities to put in place mechanisms for dealing with climate change.

2. DISTRIBUTION, FUNCTIONS AND VALUES OF FRESHWATER ECOSYSTEMS IN SOUTHERN AFRICA

2.1 Freshwater Wetlands in Southern Africa

This paper uses the definition of wetlands as adopted by the Contracting Parties to the Ramsar Convention which is as follows "areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed six meters" (Dugan, 1990). Following this definition, and using the classification of wetlands proposed by Dugan (1990) and Masundire (1995) freshwater wetlands in Southern Africa include a variety of natural and human-made (artificial) (Table 1). Figure 1 depicts the distribution of these wetlands in the region.

Table 1: Examples of Freshwater Wetlands in Southern Africa.

Type	Characteristic Features	Some Examples
A. Natural	Formed by natural causes	A1 – A10
A1. Riverine - Perennial – Rivers	Flowing water throughout the year	Zambezi, Okavango, Limpopo, Orange, Rovuma, Shire, Kafue, Pungwe, Chobe, Save Rivers.
A2. Riverine - Perennial - inland deltas	Terminal ends of inland drainage systems	Okavango Delta, Makgadikgadi Pans
A3. Riverine – Perennial – floodplains and swamps	Permanently flooded floodplains, size varies seasonally	Malagarasi (Tanzania), Barotse, Luena, Lukanga, Kafue Flats (Zambia), Linyati-Chobe, Okavango (Botswana), Marromeu, Pungwe, Limpopo (Mozambique)
A4. Riverine - Temporary -Seasonal rivers	Flowing water for part of the year usually during or following rainy season	Numerous tributaries of the perennial rivers
A5. Riverine - Temporary - Riverine flood plains	Seasonal flooded river flats, grasslands	As in A3 above
A6. Lacustrine – Permanent	Shallow littoral zones of permanent lakes	Littoral zones of Lake Malawi, Bangweulu, Lake Tanganyika
A7. Lacustrine – Seasonal	Shallow lakes with large seasonal variations in size	Bangweulu, Mweru-Wantipa (Zambia) Rukwa (Tanzania), Liambezi, Ngami, Nxai (Botswana), Malombe, Chilwa (Malawi)
A8. Palustrine – Permanent	Permanent freshwater marshes and swamps with emergent vegetation whose bases lie below the water table for most of the growing season	As in A6 & A7
A9. Palustrine – Seasonal	Seasonal freshwater marshes and swamps with or without emergent vegetation.	Numerous throughout Southern Africa, includes dambos.
A10. Palustrine – Pans	Natural depressions collecting water for varying lengths of time	Kazuma Pan (Zimbabwe) Nxai Pan, Makgadikgadi Pan, Nogatsau Pan (Botswana) Etosha Pan (Namibia)
B. Human-made (Artificial)	Created deliberately or unintentionally by human activities.	B1 – B4
B1. Reservoirs or Impoundments.	Created by damming of rivers, variable in size from small, medium to large dams, usually built for purposes other than creating wetlands e.g. water supply, hydro power	Cabora Bassa (Mozambique), Kariba (Zambia/Zimbabwe), Katse (Lesotho), Kafue (Zambia), Mnjoli (Swaziland), Chivero (Zimbabwe) Vaal, Hartebeespoort (South Africa) Shashe, Letsibogo (Botswana)
B2. Excavation burrow pits	Left after extraction of gravel, soil, sand used in construction. Hold water for varying lengths of time.	Occur throughout the region
B3. Wastewater treatment	Sewage treatment ponds or lagoons	Occur throughout the region, associated with major population centres.
B4. Aquaculture	Ponds or lagoons created for farming fish, prawns or other products	Chilanga (Zambia), Kariba (Zimbabwe)

Source Dugan (1990) and Masundire (1995)

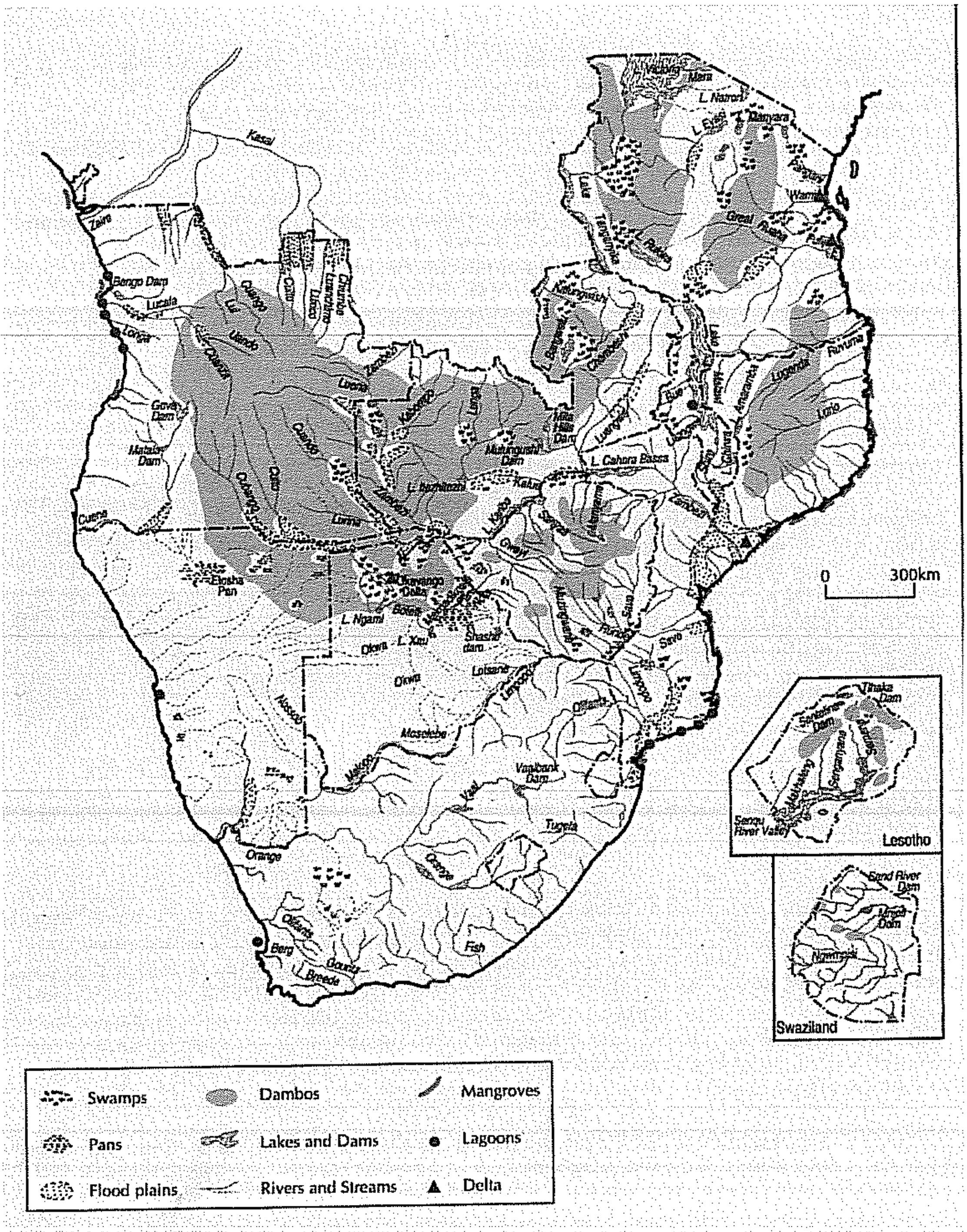

Fig. 1 Geographical Distribution of Some of Freshwater Wetlands in Southern Africa. (Water in Southern Africa, SADC/IUCN/SARDC, 1996)

2.2 Current Water and Wetland Uses and Management

Both natural and human-made wetlands provide a myriad of goods and services while contributing to the maintenance of wetland ecosystems Goods include all the direct use products such as fish, timber, water, thatching grass, medicinal plants, etc. that humans obtain from wetland ecosystems. Services are mainly indirect use values such as flood mitigation, water purification, and nutrient retention. These values are summarised in Table 2.

Table 2 Values of Wetland Ecosystems in Southern Africa

Use Values			**Non-Use Values**
Direct "goods"	**Indirect "services"**	**Option "services"**	**Existence "services"**
Fish	Nutrient retention	Potential future use	Biodiversity
Timber	Pollution abatement	Research sites	Cultural heritage
Fuelwood	Flood control		Uniqueness aura
Recreation	Groundwater recharge		Religious shrines
Transport	Ecosystem support		Ecosystem maintenance
Tourism	Sediment trapping		Wilderness aura
Thatch grass	Shore-line stabilisation		Habitat
Wildlife	Micro-climate maintenance		
Medicines	Aesthetic beauty		
Hydro power			
Pasture			
Domestic Water supply			
Irrigation Water supply			
Industrial Water supply			
Wastewater Discharge			
Sand			
Croplands			
Minerals			
Peat			

Modified from Barbier*et al.* (1997)

Different wetlands offer different suites of these goods and services (Table 2). For example, the Lake Kariba and its associated wetland ecosystems are used for hydropower generation, domestic supply, aquaculture, recreation, tourism, irrigation, fishing, transport, fuelwood, etc. There are, however, dangers to human well being that emanate from wetlands, e.g. flooding, diseases such as bilharziasis, malaria, trypanosomiasis, elephantiasis, and others that are water-borne. The balance of values and negative impacts vary from one wetland to another.

Current water use by different sectors is summarised in Table 3, but data on supply were rather difficult to collect within the limited time available for the study. It is evident (Table 3) that irrigation accounted for about 60% of total regional water demand by 1995, the rest, i.e. domestic and industrial use, stock, mining, and nature accounted for 40%. Not all countries provided estimates for water demand to support natural ecosystems because there are currently no reliable tools to accurately estimate how much water is required to maintain forests, grasslands, wetlands and all the other ecosystems, so this is an area that requires further work. That agriculture accounted for the bulk of the demand is not surprising because it is reflective of the global trend. Globally it is estimated that agriculture accounted for 69% of water use between 1996 and 1997 (Sherbinin, 1998).

Table 3: Human Population (Million) and Sectoral Water Demands in Southern Africa

1995 (MCM)

Countries	Population	Domestic and industry	Stock	Mining and energy*	Irrigation	Nature	Total
Angola	11.5	1,720	272	15	750	-	2,757
Botswana	1.5	175	44	65	47	6	150
Lesotho	2.1	84	19	5	160	-	268
Malawi	11.1	730	23	5	1,820	-	2,578
Mozambique	17.9	135	65	10	3,000	-	3,210
Namibia	2.5	200	70	15	248	5	538
South Africa	41.5	10,397	368	1,937	12,764	4,702	30,168
Swaziland	1.2	25	13	2	331	140	511
Tanzania	32.5	1,690	70	10	10,450	-	12,220
Zambia	10	532	60	20	1,580	-	2,192
Zimbabwe	11.3	697	30	30	4,980	-	5,737
Total	144.2	16,385	1,034	2,113	36,130	4,853	60,515

Source SADC/IUCN/SARDC (1996)

As a sign of recognition of the values of wetlands, all countries of Southern Africa have a government institution that is responsible for water development, supply, and management in different ministries. Where they exist, specific responsibilities for wetlands conservation and management, fall under the jurisdiction of government institutions responsible for natural resources. For example, in Zambia, wetlands are the responsibility of the Ministry of Environment and Natural Resources. While there are such institutions and elaborate water management strategies throughout the Southern Africa, systematic approaches to management and regulation of wetlands (Table 4) appear to be lacking.

Table 4: Some Aspects of Water Resources and Wetlands Management Statutes in Southern Africa

Country	National Water Law	National Water Policy	National Water Master Plan	Responsible Authority	Ramsar Convention	National Wetlands Policy
Angola	No	No	No	National Directorate of Water	No	No
Botswana	No	No	Yes	Department of Water Affairs	Yes, 1997	Being formed
Lesotho	No	No			No	No
Malawi	Yes	Yes	Yes	Water Resources Board	Yes, 1997	No
Mozambique	Yes	Yes	No	National Directorate of Water		No
Namibia	Yes	Yes	No	Department of Water Affairs	Yes, 1995	No
South Africa	Yes	Yes	Yes	Department of Water Affairs	Yes, 1975	No
Swaziland	No	No	No	Ministry of Natural Resources and Energy	No	No
Tanzania	No	Yes	No	Directorate of	Yes, 2000	No

				Rural Water Supply, Directorate of Urban Water Supply		
Zambia	No	Yes	No	Department of water Affairs	Yes, 1991	No
Zimbabwe	No	No	No	National Water Authority	No	No

Source **Country Reports in the Water Sector-Lesotho 1997/98 (unpublished)**

The lack of a systematic approach is also evident from the inability of Southern African states to recognize the inter-linkage between water and wetlands. In unpublished Country Reports in the Water Sector (1997/1998) by all Southern African states, there was no mention of wetlands being directly linked to water resources management. These reports were prepared for the First Round Table Conference on Integrated Water Resources Development and Management in the Southern African Development Community (SADC) region, which was held in Geneva in December 1998. While the importance of wetlands to water resources management may be implied from terms such as "integrated water resources management", the term "wetlands" was not used at all in the Country Situation Reports in the Water Sector for the 11 Southern African states covered in this study. The SADC Protocol on Shared Watercourse Systems also does not use the word "wetlands" preferring to use "watercourse systems".

Accession to the Ramsar Convention on Wetlands may be used as the only indication of the seriousness with which wetlands are viewed in a country. Six of the eleven Southern African states have ratified the Ramsar convention. However, one of the obligations of the Contracting Parties to this convention is that they must develop national policies to guide the wise use of wetlands. To date, however, none of the region's countries has a national wetlands policy, with the exception of Botswana, which has a draft policy that is currently being reviewed. However, there is a need to mention that countries that have designated Ramsar sites, e.g. Malawi and Botswana, have formulated specific management strategies for those wetlands. The decoupling of water and wetlands is an issue that needs to be addressed with a view to mainstream the concept that water and wetlands be managed as intimately connected entities.

2.3. Expected Future Use of Water and Wetland Resources

In the absence of water supply data, this study is rather constrained in making any meaningful deductions as to whether the demand is excessive or not (Table 7). Given the estimated natural rate of increase of the region's population, i.e. between 2 and 3.2%, demand is unquestionably going to increase (Table 5). In fact the First SADC Round Table Conference on Integrated Water Resources Development and Management noted that, as expected, the growing population would lead to increased demand for domestic use, water to produce food, and volume of waste that would compromise water quality through pollution. These same phenomena were also noted in the State of the Environment in Southern Africa (SARDC, 1994).

Table 5: Projected Population (Million) and Water Demand (MCM) by 2020 in Southern Africa

Country	Growth Rate %	2020 Population	2020 Water Demand (MCM)	% increase on 1995 water demand
Angola	2.9	17.4	5 634	+ 104
Botswana	2.5	2.3	278	+ 85
Lesotho	2	2.9	440	+ 64
Malawi	3.2	20.1	5 666	+ 120
Mozambique	2.3	27.6	5 668	+ 77
Namibia	2.4	2.6	973	+ 81
South Africa	2.5	73.4	55 930	+ 85
Swaziland	2.7	1.5	995	+ 95
Tanzania	2.8	52.0	24 372	+ 99
Zambia	2.7	15.8	4 267	+ 95
Zimbabwe	3.1	21.0	12 397	+ 116
TOTAL		236.6	116 619	+ 93

Source SADC, IUCN & SARDC, (1996), SADC (2000a), Stanley Consultants (1995)

It may be contended that the estimated water demand for 2020 is fraught with uncertainties because they are dependent on assumptions that may be inaccurate, e.g. population growth rates, per capita water demand, industrial growth, and increases in food production. Zhou and Masundire (1998) showed that, in Botswana, assuming a no-cure for AIDS scenario, the total population in 2021 will be 24% less than has been predicted without HIV and AIDS. It is, therefore, highly likely that estimates based on demographic trends that do not take into account the demographic impact of HIV and AIDS may be unreliable.

The uncertainties of estimating future demands notwithstanding, Table 7 shows that water demand for the whole of Southern Africa will grow by 93%. In view of the projected rise in demand, the major challenge is how the region will meet this demand. Sherbinin (1998) described the relationship between water and population dynamics as reciprocal, location-specific, transcending national boundaries and varying over time. For example as human population increases, demand for water increases while supply is reduced. When water supply is low, however, it may cause reduction in human populations – often in a drastic manner such as famine. The ability of the wetlands and related ecosystems to continue to provide goods and services (Table 2) is also another challenge because apart from the large water demand to be met, future water supplies are likely to be impacted on by changes in global climate.

3 LINKS BETWEEN CLIMATIC VARIABLES, HYDROLOGICAL REGIMES, AND STATE OF WETLANDS IN SOUTHERN AFRICA

This section examines the past climatic variability phenomena which could be considered uncharacteristic. Such experiences of impacts of past climatic events will also shed light on what to expect should climate change occur. Past climatic events in Southern Africa have been assessed using 2 methods, i.e. evidence of sustained temperature, precipitation, runoff and hydrologic trends, and uncharacteristic intensity and occurrence of extreme events such as floods and droughts in recent times.

3.1 Climatic Characteristics

The Southern African sub-continent is dominated by 2 climate regimes, i.e. the semi-arid and semi- humid in the east, then the dry and hyper-arid in the west (Darkoh, 1989). Influenced by these climate regimes, there are wide variations in degrees of aridity and wetness in the region, which mainly depend on the level of rainfall, temperature, vegetation, wind, topography and soil. To provide some understanding of the important climate variables, the succeeding sub-sections briefly describe rainfall, temperature, and evapo-transpiration patterns of the region.

3.1.1 Rainfall

The main cause of rainfall in Southern Africa is the Inter Tropical Convergence Zone (ITCZ). The onset of the rains, however, depends on its mobility and position in the region. The ITCZ is a zone of intense rain cloud development when the South East Trade winds (from this part of the region) collide with the North East Monsoons (from the North). The movement of the ITCZ from the equator marks the start of the rain season in the hemisphere. In a normal year, the ITCZ fluctuates between mid Tanzania and Zimbabwe but never moves beyond the Limpopo River in the south. Tropical cyclones in the Mozambique Channel, the Congo Air Masses and South East winds in the region also play a role in the rainfall pattern of the region (Chenje, 2000).

The ITCZ phenomenon is contrasted by the Botswana Upper High Influence, which control drought episodes and uneven rainfall distribution. The Botswana Upper High Influence is a high-pressure cell over Botswana, 6 km above sea level, which creates an unfavourable condition for rainfall by pushing the rain bearing ITCZ and active westerly cloud-bands out of the region.

Table 6: Rainfall, Potential Evaporation and Runoff Patterns in Southern Africa

Country	Rainfall range (mm)	Average rainfall (mm)	Potential evaporation range (mm)	Total Surface Runoff (mm)
Angola	25-1600	800	1300-2600	104
Botswana	250-650	400	2600-3700	0.6
Lesotho	500-2000	700	1800-2100	136
Malawi	700-2800	1000	1800-2000	60
Mozambique	350-2000	1100	1100-2000	275
Namibia	10-700	250	2600-3700	1.5
South Africa	50-3000	500	1100-3000	39
Swaziland	500-1500	800	2000-2200	111
Tanzania	300-1600	750	1100-2000	78
Zambia	700-1200	800	2000-2500	133
Zimbabwe	350-1000	700	2000-2600	34

Source: Pallet (1997)

The rainy season in the region generally extends from late October to April while the dry spell stretches from May to October although, the rains are bimodal in the North East of Tanzania, i.e. long rains between March and May and short ones between December and February (United Republic of Tanzania, 1999). The other exception is in the Mediterranean climate of the Cape in South Africa where rains also come between the months of June to September.

Rainfall distribution significantly varies spatially across the region. The mean annual rainfall ranges from <250 mm in the west and southwest in Namibia and South Africa, to 1100 mm in Mozambique (Table 6). The driest parts of the region are in Botswana, Namibia and some parts of South Africa. Wide ranges of rainfall are also recorded within the countries; an example is South Africa where rainfall has a wide range of 5 to 3000 mm.

Over the last decades Southern Africa has experienced wider fluctuations in annual rainfall patterns that have led to extreme conditions of drought episodes and floods. For the last 30 years the rainfall pattern demonstrated by the annual rainfall of Botswana (semi arid to arid climate) and Mozambique (wet climate) between 1970 and 2000 show rainfall variability by fluctuating from dry years to wet years (Fig.2). The data show notable dry spells for Botswana (< 500mm/year) in 1971-72, 1978, 1981-1986, 1989 and 1991-93. Dry spells in Mozambique (< 700mm/year) were in 1970-71,1974, 1979-80, 1982-83, 1986-89, 1991-92 and 1994-1995. In both cases there were 3 to 4 years dry spells in the 1970s, 7 years in the 1980s and 3 to 4 years in the 1990s. Beyond 1995 annual rainfall has continued to increase to 2000 more significantly for the wetter Mozambique. The dry spells have exposed the region to suffering, so should the climate change, the impacts in the region will be more severe.

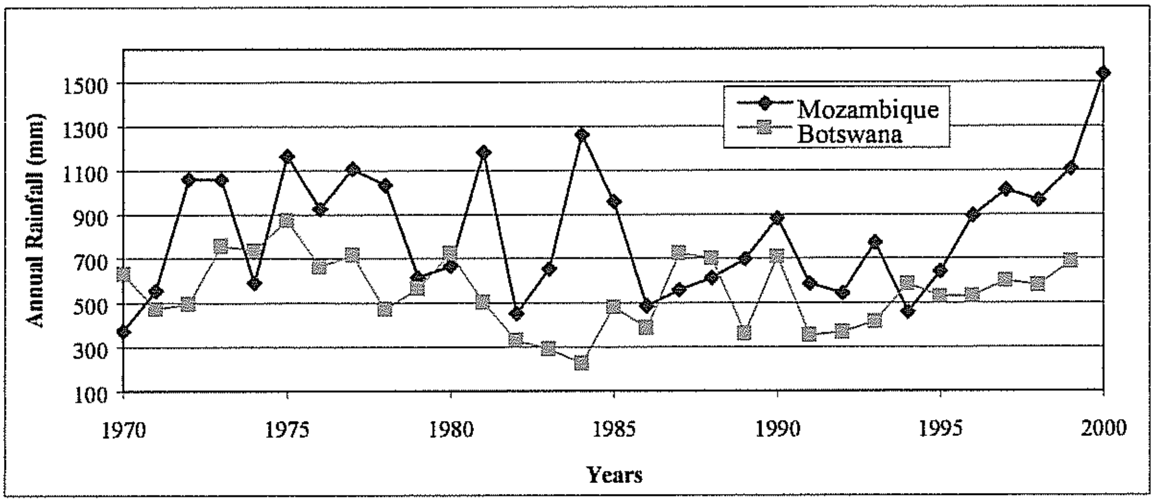

Fig. 2: Annual Rainfall Pattern for Botswana and Mozambique 1970-2000

The hydrological trend, as depicted by runoff data from major river basins in the region suggests a decline of about 17% over the past decade (IPCC-WGII, 2001). Some basins, however, e.g. the Zambezi River show wide fluctuation yearly, but wet and dry periods are discernible over the last 75 years (Fig.3).

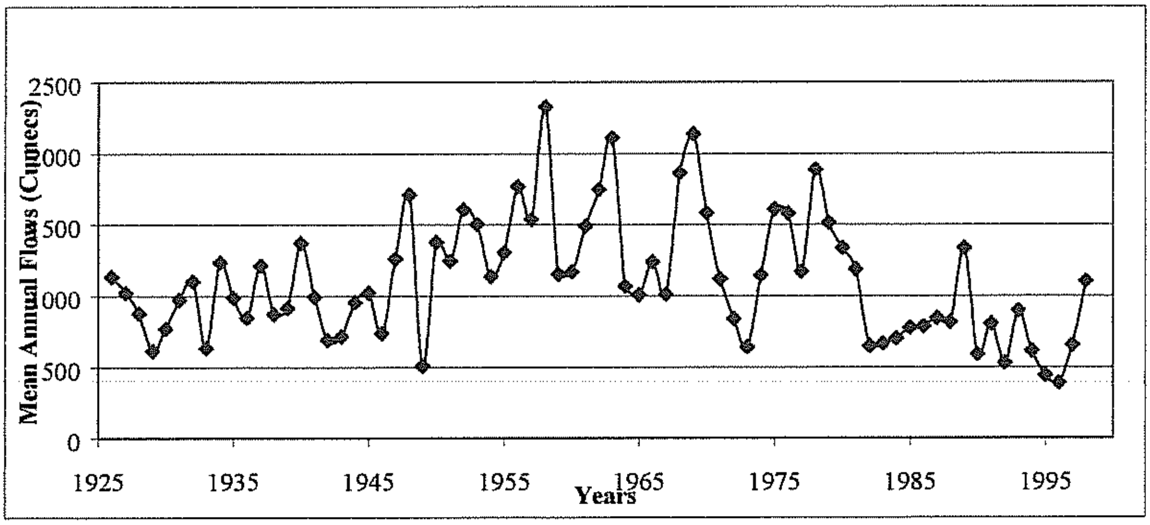

Fig 3: Mean Annual Flow of the Zambezi River as Monitored at Victoria Falls 1924/25 to 1997/98. ***Source*** **Zambezi River Authority (2001)**

At Victoria Falls, the Zambezi River drains an area of 507 600 km^2, equivalent to 39% of the whole basin. This percentage is a significant portion of the Southern African sub-continent such that one could take the flows at Victoria Falls as representative of hydrological events in the region.

The period 1924/25 to 1944/45 is considered to have had medium mean annual flows with a mean of about 1000 m^3/sec. This was followed by the period from 1946/47 to 1979/80, which was characterised by high mean annual inflows of around 1500 m^3/s. The past 20 years, however, from 1980 to 1999/2000, has been characterised by a considerably low mean annual flows of about 700 m^3/s. Although not conclusive, it is possible that the continued trend to lower mean annual rate of flows from 1500 m^3/s in 1946 to 700 m^3/s in the last two decades could be a sign of changes in climate.

Studies by Magadza (1996), and Conway and Hulme (1993) show that under the present climate regime, several large lakes and wetlands show a delicate balance between inflow and outflow resulting from evaporative losses. Specifically, Calder et al. (1995) reported that Lake Malawi had no outflow in more than a decade in the earlier part of the last century for similar reasons. Since the 1980s, some wetlands such as Lake Ngami in the NW of Botswana, Lake Liambezi on the Linyati River, and Lake Chirwa in Malawi have dried up for varying lengths of time. Over the same period, the floodgates at Lake Kariba remained closed for 20 years until 2000. These hydrologic trends show that water and wetlands resources have been vulnerable to climatic variability, and hence extreme impacts can be anticipated under climate change.

The water losses are further dependent on vegetation type, topographic, and soil characteristics. Vegetation type determines how much water will be released to the atmosphere through transpiration. Topography, and soil determine how much water will seep into the ground and what will flow as runoff. High topography and shallow soil layer and presence of solid surface geology are conducive for runoff. In fact, there are large differences between potential flows directly estimated from mean annual rainfall for countries of the region and the recorded runoff (Table 7). Only 13% of mean annual rainfall in the region eventually becomes runoff and the balance is accounted for by groundwater seepage and evapo-transpiration. It is estimated that in the Okavango Delta about 97% of water is lost to evapo-transpiration and ground seepage (SARDC/SOE, 1999).

Table 7: Rainfall versus Runoff in Southern Africa

Country	**Average Rainfall (mm)**	**Total Surface Runoff (m^3)**	**Surface runoff to rainfall ratio %**
Angola	997	130	13
Botswana	233	0.35	0.2
Lesotho	21	4.13	20
Malawi	119	7.06	6
Mozambique	879	220	25
Namibia	206	1.24	0.6
South Africa	612	47.45	8
Swaziland	14	1.94	14
Tanzania	709	74	10
Zambia	602	100	17
Zimbabwe	273	13.1	5
Total	**4665**	**599.27**	**13**

Source Pallet (1997)

The driest countries, Botswana and Namibia, have the least surface runoff to rainfall ratio of below 1%, followed by South Africa, Zimbabwe and Malawi, which have ratios of <10%. The scarcity in runoff, and hence fresh water resources are likely to be exacerbated by the increase in temperature predicted to occur as a result of global warming and climate change.

3.1.2 Temperature

In Southern Africa, there are small seasonal variations of temperature depending on altitude, latitude, and proximity of water bodies. The general range of daytime temperatures in the region is between 25-30° C (SARDC/IUCN/SADC, 1994). The maximum day temperatures can, however, exceed 40°C in low altitudes. These high temperatures coincide with the greater part of the rain reasons between October and February, and they contribute to high evaporation and evapo-transpiration rates. Extreme low temperatures of below 0°C also occur in the region particularly in winter over the highlands, but their effect on water availability is not as relevant as for the high temperatures.

The scientific basis of climate change (IPCC-WGI, 2001) concludes that globally averaged surface temperatures have increased by 0.6±0.2°C over the 20th century. Countries of the Southern Africa region are already depicting rises in temperatures in their data. Records also reveal that temperatures have risen by 0.5°C over the past 100 years (Chenje, 2000). The graph for temperature changes between 1925 and 1995 for Gaborone (Fig 2) suggests a warming trend since the last twenty years. It is, therefore, not surprising that historical trends in the mean annual temperatures over Botswana show an increases of about 1.0°C (Ministry of Works, Transport and Communication, 2001)

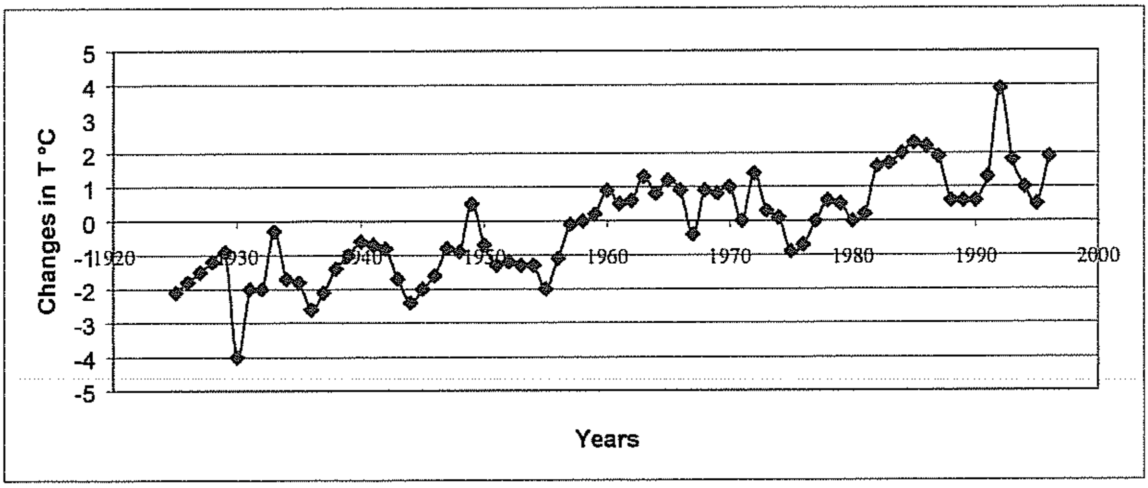

Fig 4:Changes in Minimum Temperature (°C) for Gaborone; 1925 to 1995 (Plotted using data obtained from the Department of Meteorological Services of Botswana)

South Africa also registered an increase of 0.2°C in the 1990s (DEAT, 1999). These two examples suggest that changes in climate may be already occurring in the region thereby most likely affecting its water and wetland resources.

3.1.3 Evapo-transpiration

Areas of lowest annual rainfall also coincide with lowest annual relative humidity and high solar energy hence aggravating water shortage. Some dry parts of the region, e.g. the Makgadikgadi Pan in Botswana, are prone to high wind speeds and dust storms that exacerbate water losses to the atmosphere. Pallet (1997) estimates that potential evaporation (the indicator for surface water evaporation) ranges from 1100 to 3000 mm in the region. This potential evaporation far exceeds rainfall in the drier parts of the region; virtually each country has areas where such deficits occur.

3.1.4 Additional Evidence that Changes may be Affecting Freshwater Ecosystems in Southern Africa

Additional evidence that changes could be having impacts on water and wetlands in the region is in the form of extreme events, e.g. drought and floods, severe cold spells, and heat waves in certain cases. As stated earlier on, notable drought periods in the region are 1946/47, 1965/66,1972/73, 1982/83, 1986/87, 1991/92, and 1994/95. These data indicate that there have been three drought events in 27 years, i.e. 1946/47 up to 1972/73, but 4 spells in 12 years (between 1982 and 1995), suggesting that in recent times the frequency and intensity are increasing. In fact, the 1992-93 and 1994-95 dry spells have been described as the most severe (SADC/ IUCN/SARDC, 1996).

In recent years, the region has also started experiencing intense flooding, an event that is not consistent with the long-term climate of the region. This event has been particularly evident between 1999 and 2002, the period when Southern Africa experienced variable intensities of rainfall. For instance, between February 5th and 6th, 2000, tropical cyclone Connie caused flooding in Mozambique, Botswana, South Africa, and Swaziland. Media reports indicated that this was the worst flooding across Southern Africa in 50 years (National Climatic Data Center, 2000). Thousands of people in Mozambique were either killed or displaced. Within the same month February 22nd, tropical cyclone Elaine struck the region, drenching an already flood-stricken Mozambique and the larger part of the region (Botswana, South Africa, Swaziland, Zambia and Zimbabwe). Following cyclone Elaine, the Limpopo River in Mozambique recorded a flood that was estimated to be a once-in-a-thousand years event (SADC, 2000b). High waters in the Zambezi River, exacerbated by the effect of managed dams, namely Kariba, Kafue, Cabora Bassa and others within the basin, also caused severe floods in the Delta (Mozambique).

At the Kariba Dam itself, the high rainfalls since 1999 have caused levels of water to rise beyond what most people had ever experienced in more than 20 years. Masundire (personal communication) gives an anecdote of this event. As water rose in Lake Kariba during the 1999/2000 rainy season, at least 2 luxury houses that had been built below the 490 m a.s.l contour – the highest water level, were completely submerged. A senior government official in Siavonga, Zambia owned one of the houses while a prominent businessman in Kariba Town, Zimbabwe owned the other. Both owners had lived on Lake Kariba for over 25 years. The senior Zambian government official is said to have attempted in vain to force the Zambezi River Authority, who own and manage the dam, to open the floodgates so as to save his house. In what became a rare tourist boom for Kariba, more than 30 000 people converged at the dam to witness the opening of the floodgates for the first time in 20 years.

4 PROJECTED CLIMATE CHANGE AND IMPACTS IN THE REGION

Projected impacts of climate change for Southern Africa have been based on estimates of likely vulnerability of climate parameters presented in various studies conducted for the region, among them IPCC- WGI (2001) and IPCC-WGII (2001) as shown in Tables 8 and 9. According to predictions made by Arnell (1999), the effects of a decline in rainfall will not only be increases in most evaporation rates, but also reductions in surface run-off within some of the major basins of the region. Should this indeed be the case, then there are going to be reductions in river flows and hydrological regimes in wetlands thereby resulting in water deficits in view of the projected increases in water demand (Table 5).

Table 8: Predicted Changes in Precipitation, Potential Evaporation, and Runoff in Major River Basins of Southern Africa Under a Climate Change Scenario

River Basin	% Change in Precipitation	% Change in Potential Evaporation	% Change in runoff
Congo	+ 10	10 to 18	10 to 15
Zambezi	-10 to-20	10 to 25	-26 to –40
Rovuma	-10 to5	25	-30 to –40
Limpopo	-5 to-15	5 to 20	-25 to –35
Orange	-5 to 5	4 to 10	-10 to 10

Source IPCC-WGII (2001)

Table 9: Projected Climate Change and their Impacts in some Southern African Countries (2050 - 2075). Figures in Parenthesis are Years when Climate Change is Predicted to Occur.

Country	Temperature Change	Rainfall Change (mm/day)	Potential Evaporation (%)	Runoff Change (%)	Models Used
Botswana (2075)	1-3°C	-10 to -25%		-6 to -53%	UKTR, CCC, OSU
Lesotho (2075)	+2.0 - 4.7°C	-0.1 -0.33			UKHI, CCC, GFDL, OSU, GISS & UKTR
Mozambique (2075)	1.8 - 3.1°C	-2 to -9%	9 - 13%		GFDL, UKMO, UK98, GENESIS, GISS
South Africa (2050)	1-3°C	-5 to -10%			Genesis, HadCM2, CSM
Tanzania (2075)	2.5-3.0 °C [a] 3-3.9°C [b]	-5 to -15% [c]		+11- -10%	UK98, GISS, GFD3, CCC
Zimbabwe (2075)		-15 to –19%	+7.5 - 132%	-50%	GISS, GFDL, CCC

The OSU model gave a 10-20% increase in rainfall, while the UKTR gave a 0.53mm/day increase in rainfall. [a] in warmest months, [b] in coolest months, [c] in bimodal rainfall areas

Sources Ministry of Works, Transport and Communications-Botswana (2001), Ministry of Natural Resources-Lesotho (2000), Government of Mozambique (1999), DEAT (2000), United Republic of Tanzania (2000), and Ministry of Mines, Environment and Tourism-South Africa (1997)

4.1 Predicted Rainfall

The IPCC-WGII (1998, 2001) concluded that Southern Africa will get drier if climate change occurs, and that the region will find it difficult to cope with the impacts given the present level of preparedness. Simulations by Hulme *et al.* (2001) indicated reductions in precipitation in Southern Africa for the next 100 years (IPCC-WGII, 2001 ch. 10). Under the base case warming scenario of 1.7°C (IPCC-WGI, 2001), Southern Africa's precipitation is expected to decrease by 5-20% in all the major river basins of the region except the Congo Basin where precipitation is expected to increase by 10% (Table 8). Basing on individual country analysis, some countries may have more severe shortage in rainfall. Botswana and Zimbabwe may have as much as 25% and 19% shortfall respectively (Table 9). The predicted increase in rainfall and runoff in the Congo Basin may, therefore, be a basis to plan for inter-basin water transfers to supply the drier countries in the south and east of the region.

4.2 Predicted Temperatures

For the range of scenarios developed (IPCC-SRES, 2000), the global average surface air temperature is predicted to increase by 1.4 to 5.8°C by 2100. The Southern African region is expected to register a temperature rise under climate change of 0.2°C to 0.5°C per decade with warming being greatest in semi arid margins of central Southern Africa (Hulme et al. 2001; IPCC-WGII, 2001). Overall, countries in Southern Africa are predicted to have a temperature rise between 1°C and 4.7°C (Table 9). In comparison, these increases are about 3 to 4 times higher than the observed temperature rise during the drought episodes of the 1980s and 1990s, which was only 0.3°C (Ministry of Works, Transport and Communication, 2001)

4.3 Predicted Evapo-transpiration

Evapo-transpiration under climate change is predicted to increase by between 4% and 25% in the regional basins (Table 8). This increase will most likely aggravate evaporation rates from the numerous dams, lakes and wetlands. While most countries have estimated similar increases, the anticipated rise in potential evaporation estimated for Zimbabwe ranges between 7.5% and 132% (Table 9), representing the varied climate regimes across the country.

4.4 Predicted Runoff and Hydrological Regimes

Arnell (1999) shows that the greatest reduction in runoff by 2050 in Africa will be in the Southern Africa region, thereby suggesting that water use to resource ratio[2] changes will put countries in the high water-stress category. Combining the shortfall in rainfall and the effect of increases in potential evaporation, the resultant reduction in runoff in the major river basins of the region will be up to 40% (Table 9). The impact is expected to be most severe in the Rovuma Catchment in Tanzania, and the Zambezi Basin whose resources are shared by the 8 countries, i.e. Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe.

Estimates of climate change impacts on hydrological resources made for Botswana (Zhou and Masundire, 1998; Ministry of Works, Transport and Communication, 2001), Lesotho (Ministry of Natural Resources, 2000), Mozambique (Government of Mozambique, 1999), South Africa (DEAT, 2000), Tanzania (United Republic of Tanzania, 2000) and Zimbabwe (Ministry of Mines, Environment and Tourism, 1997) all point to a drier climate for the region under doubling of atmospheric concentrations of CO_2, which is the situation assumed to represent a climate change situation. Depending on locations in the countries, most of the GCM models used in the impact analysis of climate change indicated a decrease of up to 50% in runoff for some countries (Table 9).

In rare cases the GCMs suggested that the region would get wetter under climate change than present. For example, the OSU model projected a 10 to 20% increase in precipitation for Botswana while the UKTR and CCC predicted a decrease of similar magnitude. While these results are generalized for each nation, there are in-country variations. Some areas are estimated to have an increase in runoff while others will have a deficiency. In Tanzania, for instance, it is predicted that the south-eastern parts of the country, where the Rufiji River is located, will have an increase in rainfall, and hence runoff increases of 5% to 11%. In contrast, the coastal areas of the north and north-eastern parts, where Pangani River is located, will have a runoff shortfall of 6% to 9% (United Republic of Tanzania, 2000). Such in-country differences are expected across the region and any water planning should take consideration of these spatial variations in water availability.

4.5 Predicted Sea Level Rise

Rises in sea levels is the other expected impact of climate change. IPCC –WGII (2001) estimated a sea rise worldwide of 0.08 to 0.88m by 2100 but varying by region (IPCC-SRES-2000) with consequential damage to coastal infrastructure and contamination of fresh groundwater by salt intrusion near the coast and possible direct threat to many people living

[2] water use to resource ratio=water demand to available water resources if less than 1 then it's a case of water stress

along coastline. Similarly, those countries in Southern Africa with substantial coastline are expected to suffer inundation close to the coast. In Tanzania, it is estimated that should the sea rise by 1 m along its 800 km coastline, 50 000 ha of land will be inundated. Such inundation will contaminate groundwater, flood deltas and some marine wetlands and destroy large amounts of biodiversity. South Africa has estimated a possible sea rise of 0.4 m to 0.55 m at Port Nolloth by 2100 should the climate change (DEAT, 1999). Such a rise is also expected to cause salt intrusion into freshwater groundwater near the coast and damage to coastal infrastructure (DEAT, 1999).

4.6 Extreme Events and Water Quality

Climate change is predicted to cause extreme events in most countries in Southern Africa. Lesotho, for instance, predicted a higher frequency of drought episodes and intense rainstorms and severe winters. South Africa, on the other hand, predicted that climate change would alter the magnitude, timing, and distribution of rainstorms that will cause floods.

Consequent upon these extreme events, water quality is expected to deteriorate. The SADC-Water Sector (2001) has raised concerns of possible damage to sewerage infrastructure during floods, which can result in water contamination. Drought events are expected to result in lack of adequate water to deal with sanitation. Deficits in groundwater resources will lead to salinity, especially in the semi-arid to arid countries where recharge is already low.

4.7 Effects on Ecological and Socio-economic Systems

Impacts of increased temperature, reduced precipitation and runoff will be felt in many situations with varying severity. Such severity on water supply, agriculture, infrastructure and human health are presented below. Socio-economic impacts arising from climate change impacts on water and wetlands are likely to include shortage of supply of water, food insecurity, poor health, extreme events, and damage to infrastructure.

4.7.1 Water Resources

The impact of precipitation and enhanced evaporation could have profound effects in some wetlands, lakes and reservoirs. Sensitivity analysis carried out for water storage in Zimbabwe's main reservoirs during the 1991-1992 drought cycle indicated that with a 2°C increase above the mean temperature, and a potential evaporation exceeding the long term seasonal average by between 30% and 90%, the quantity dwindled to 10% of the capacity (Magadza, 1996). Many rural wells and boreholes dried up and urban water supplies were severely limited in the country, resulting in unprecedented rationing (Shela, 1996).

During the same period, Lake Malawi's level fell to record lows of the early 1930s. Its harbours and ports could hardly be used for container cargo and passenger ships as the Lake was below the operating level of 475 m by ±2 m thereby forcing big ships to ground. Concomitantly, there was a drop in fish catches and severe shortages of water for irrigation, hydropower, and the environment. An emergency Shire River flow augmentation project worth US$ 15 million was required to protect investments in hydropower, irrigation and the environment (Shela, 1996). Water level data for Lake Kariba also illustrates that minimum flows coincided with periods of low rainfall (Fig. 5). The dam reached levels close to the minimum operating level of 475 m a.s.l in the mid 1980s, early 1990s and mid 1990s. That both Lakes Malawi and Kariba were affected suggests firstly that large and small water bodies would be impacted in the event that the climate changes. Secondly, it is an indication that the impacts will be regional as opposed to local.

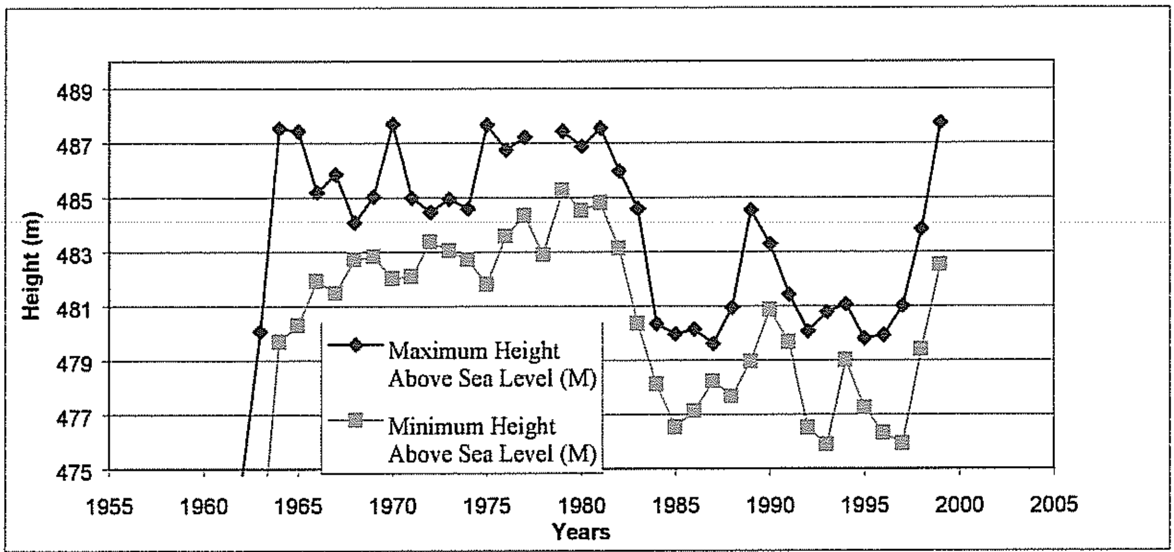

Fig. 5: Water Height Above Sea Level at Kariba Dam 1963-200
Source ZRA (2001)

Drought events have also caused negative impacts to hydropower generation. In 1991/1992 the hydro-generation at Kariba fell by 15% (Shela, 1996). During this period, about US$ 102 million worth of power was lost. This loss had ripple effects in the national economy because it resulted into a deficit of US$36 million in foreign earnings, and 3000 workers had to be retrenched. During the same period, prolonged drought episodes in Tanzania reduced the Mtera reservoir on the Rufiji River to extremely low levels thereby severely hampering the hydropower generation at the dam and Kidatu power plants. This event lead to load shedding within town and cities including Dar es Salaam, which experienced black outs for several hours almost every day, particularly during the dry seasons of 1993 and 1994 (Shela, 1996)

Considering the impact of drought episodes on the socio-economy of the region, it can be postulated that the situation would be worse in the event that the climate does change as predicted using different GCMs. For instance, a reduced per capita water consumption of less than 1000 m^3/yr and failure to meet water exports are expected in Lesotho (Ministry of Natural Resources, 2000). Water supply from dams is expected to decrease by 30 to 40% in Zimbabwe (Ministry of Mines, Environment and Tourism, 1997). South Africa will have to resort to more inter-basin water transfers from other countries such as what has already started with the Lesotho Highlands Project (Matlosa, 2000; Zhou, 2000). Such situations require prudent regional approaches to avoid conflicts among the states especially in the special cases of shared water resources.

Reduced runoff and hence water resources will also have an impact on tourism, wildlife, and water supply for recreation in the region. Drought events are known to have caused mortality in wildlife in the past (Walker et al. 1987; Mkanda and Munthali, 1991; Magadza, 1994), besides reduced water flows at sites such as Victoria Falls where the number of tourists declined. Low soil moisture and high evapo-transpiration will promote desertification, reduce forest cover and spur soil erosion and sediment discharge that could cause siltation of reservoirs. Lesotho expects 2% of topsoil removal every year with consequences of sedimentation in wetlands (Ministry of Natural Resources, 2000). Reduced water in wetlands will also probably impact on fish production and availability, biodiversity resources and ecological balance in general. This has not been studied before and is therefore an area recommended for further investigation.

4.7.2 Food Insecurity

Climate change is expected to impact negatively on agriculture. With respect to crop production, both rain-fed and irrigated lands will be affected. Considering that in Southern Africa, agriculture constitutes a significant percentage of the GDP, the impacts will have profound consequences on the economies of the region. In 1991/92, for instance, Zimbabwe's yield of maize, a staple, dropped by 70%, while overall agricultural production fell by 40%. This shortfall resulted in a massive food relief programme for 50% of the population (Shela, 1996). In Botswana, maize and sorghum production is expected to decline under climate change by 30% (Ministry of Works, Transport and Communications, 2001) while in South Africa maize productivity will fall by 10-20% (DEAT, 2000). From these events, therefore, it is prudent to speculate that food security will be a critical issue in the region.

Climate change impacts given in the National Communications of some countries in the region are expected to range from shifting or shortening of cropping season, and warming and low rainfall during the growing season. In Zimbabwe the cropping season is expected to shorten by 25% thereby affecting productivity of crops (Ministry of Mines, Environment and Tourism, 1997). The anticipated changes in the growing seasons will impinge upon food security unless cropping practices such as use of early-maturing crop varieties are adopted. The shortfall in rainfall will also result in scarcity of water for irrigation. The distribution of rainfall is an important determinant for agriculture. Experience has shown that regions that receive less than 500mm can hardly support rain-fed crop agriculture unless supplemented by irrigation. An FAO study in the Malibamatsama Basin of Lesotho indicated that with doubling of CO_2, the meteorological conditions of the Basin would lead to a 65% increase in water demands for irrigation thus bringing shrinkage to the irrigated areas from 37500 ha at present to 20000 ha[3]. In contrast, severe tropical storms will flood farms and also directly cause damage to crops thereby inflicting negative impacts on agriculture.

4.7.3 Human Health

It is acknowledged that climate change will exacerbate incidents of diseases such as malaria, diarrhoea, cholera, bilharziasis, meningitis and fevers. Malaria is actually the leading public health problem in Southern Africa; it contributes 17% of all deaths in Tanzania (United Republic of Tanzania, 2000). Incidents of malaria are expected to increase due to the anticipated warming when the climate changes. In South Africa, it is anticipated that an additional 60% of the population will be residing in malaria-prone areas as a result of changes in climate, while flooding is expected to exacerbate the spread of bilharziasis (DEAT, 2000). For the wetlands where the diseases already occur, the impact of climate change is likely to enhance their intensity. Drier conditions are expected to cause tuberculosis

[3] (Kinuthia- http:///www. brad.ac.uk/research/ijas/ijasno2/kinuthia.html

and typhoid in those parts of Lesotho which will become drier (Ministry of Natural Resources, 2000). The overall picture for the region is such that disease prevalence and intensity will increase, calling for preparedness to deal with impacts on human health because an unhealthy population cannot be expected to manage and conserve its freshwater ecosystems effectively.

4.7.4 Impacts on Infrastructure

The floods of 2000 caused considerable damage to property and infrastructure in Mozambique, especially roads, bridges, rail network and water systems (National Climatic Data Center, 2000). During the 1998/99 season, the City of Harare in Zimbabwe suffered damage to its roads because the sewer system could not cope with entrained storm water (National Climatic Data Center, 2000). In the event that the climate changes, impacts on infrastructure are likely to emanate from these extreme events. Sea level rise is expected to cause infrastructural damage to the coastline of South Africa where it would affect some harbours and ports (DEAT, 1999). From these examples, it can be deduced that similar events, but probably of greater magnitude than observed in the past, will occur should the climate change.

Countries of the region will find dealing with impacts of climate change to be more challenging than in the past if preparations are not put in place in time. Previous assessments (IPCC-WGII, 2001) concluded that the African continent is particularly vulnerable to the impacts of climate change because of factors such as widespread poverty, recurrent droughts, and over-dependence on rain-fed agriculture. Response actions are beyond the current and even the most optimistic projected economic means of most countries, especially if they will act individually, hence more the need for dialogue.

5. INSUFFICIENT STATE OF KNOWLEDGE OF CLIMATE CHANGE IMPACTS ON FRESHWATER ECOSYTEMS IN SOUTHERN AFRICA

This section documents current work in the region to address climate change impacts including vulnerability assessment, preparation of national communications, and policy development. What follows in the succeeding sub-sections is description of the state of knowledge of climate change impacts on freshwater ecosystems.

Effects of climate change on water resources in the region have been tackled in the National Communications to the UNFCCC (e.g. United Republic of Tanzania, 2000; Ministry of Natural Resources, 2000 for Lesotho, DEAT, 2000 for South Africa). Other hydrological studies (e.g. SADC-HYCOS, FRIEND, IUCN Wetland Programme) conducted independently, also present valuable information on water and wetlands resources (Table 10). The question is how to coordinate these data collection activities and create linkages between the various data sets for purposes of assessing impacts of climate change on water resources and wetlands on a regional scale. Long-term data for climate change analysis is either lacking or where it exists the quality is poor in a number of countries. In the absence of good data, the quality of predictions made from the GCM models for the region is correspondingly low. Although the results so far produced should be sufficient to commence planning for threats of climate change, the extent and quality of work done in vulnerability and adaptation assessments, as reflected in the National Communications requires refinement. Worse still, some of the countries in the region have not done vulnerability assessments of their water

resources and where it was done the coverage is limited to a few river basins due to financial constraints. What is also lacking is monitoring and evaluation of trends in the state of wetlands in the region. A general evaluation of wetlands economically is not being done for the various services and goods.
While State of Environment Reports (SOE) are considered useful to present an overview of national resources such as water, forestry, agriculture, environment and fisheries, these SOE reports are not being updated frequently enough to capture changes in the resources. For water supply (e.g. inter basin water transfers) and demand options, studies are yet to be conducted to determine how choices can help alleviate scarcity should the climate change.

With regard to policies and legislation, monitoring and enforcement of existing policies and legislation that are relevant to water and wetlands management is lacking. Regional and international conventions particularly the Ramsar, UNFCCC, CCD and CBD, and the SADC agreements and protocols have been taken up but not fully integrated in national policies and laws. This is an area that requires urgent attention, and hence it is hoped that the dialogue will consider it a high priority. The shortfall in the information for decision making on integrating climate change and water and wetlands management will thus need to be addressed in good time ahead of the severe impacts.

Considering that there are a number of initiatives addressing water and wetland issues (Table 10), when seeking opportunities for implementing the adaptation strategies for impacts of climate change, it is important to determine the extent to which new strategies could be integrated with relevant existing initiatives (Table 11). The stakeholders should also consider how to share responsibilities for implementing strategies.

Table 10. Opportunities for Implementing the Proposed Adaptation and Preparedness Strategies

Strategy	Existing Initiative	Coordination
Water Data planning and modelling	SADC-HYCOS (Zhou, 2000) and FRIEND[4] Projects, National Communications to UNFCCC (see References)	Water Resources Commission (SA); Uni. Of Dares-Salaam, UNFCCC National Focal Points
Ecosystem Approach	IUCN Wetlands Programme (Breen et al. 1997)	IUCN-ROSA
Water Supply and Demand Management	National and City Programmes	Depart of water; City of Windhoek
Updating policy/legislation	National programmes	Sector Departments and Custodian of International Conventions
Early Warning	SADC-Early Warning System	Drought Monitoring Centre-Harare
Disaster Preparedness	National Programmes	National Governments

An important approach is to use pilot projects to test feasibility of the preparedness and adaptation strategies before scaling up the efforts. Further thoughts that can contribute to the process can be brought up at the dialogue sessions planned for this water and wetlands management process.

[4] (www.nwl.ac.uk/ih/www/research/bfsafrica.html)

Table 11 Available and additional requirements to implement Proposed strategies/measures

Strategy	Available Information	Source	Additional Requirements
Improving Data for Vulnerability assessment and continual modelling	Climatic data, hydrometric data, hydro geological data	HYCOS, FRIEND, SADC Groundwater Programme national data bases	Uniformity and refinement of, and access to data across region for regional assessment. Water demand forecasts, groundwater-modelled impacts.
Ecosystem approach and community-based natural resource management (CBNRM)	Awareness and some inventories of wetlands, sectoral baseline data; Experiences with CBNRM.	IUCN Wetlands Programme, State of Environment Reports, Basin Commissions for Watercourse Management; CBNRM initiative reports	Monitored changes to wetlands. Updating SOE. Adopting CBNRM for water and wetlands management
Water supply and demand management measures	Technical information on inter-basin transfer, rain harvesting, recycling/re-use/reclamation, water pricing; water-use efficiency	Selected National and City (e.g. City of Windhoek) programmes. Cross- country projects e.g. Lesotho Highlands Project.	How to maximize water availability and alleviate water scarcity caused by climate change. Replication of best practices in irrigation and other user efficiency
Updating policies/legislation	National Acts/policies. International conventions	National reports and international convention reports, SADC reports	Integrating national and international agreements.
Insuring infrastructure			Contract agreements.
Early warning and disaster Preparedness	Weather/drought and crop/food forecasts	Drought Monitoring Centre	Flood predictions, flood control designs

6 STRATEGIES FOR PREPAREDNESS AND ADAPTATION

The climate change phenomenon brings a new challenge for water and wetland planning and management. The fact that there is no single nation, least of all those in Southern Africa, that can stop the climate from changing implies that efforts should go into managing whatever water resources that will be available and ensure that wetlands are preserved to supply future demands of water, goods, and services. Rather than prescribing what the region should do, this subsection presents questions and challenges that would enable stakeholders to come up with their own strategies or measures for preparedness and adaptation to impacts of climate change. These questions form a basis for the stakeholder roundtable conference (Appendix I).

A number of aspects relevant to future preparedness have been identified in line with the Terms of Reference, which include planning for water and wetland resources, an ecosystem-based approach to water and wetland management, water supply and demand options or measures, policies, legislation, insurance for infrastructure, early-warning system, and disaster preparedness (Table 11). These approaches are described in the succeeding sub-sections.

6.1 Planning for Water and Wetland Management

Planning is necessary in this context as it entails getting ready to deal with the impacts of climate change and look ahead in terms of meeting future demand for water and wetland goods and services. An important parameter of planning is reliable data and information, in this case its usefulness in assessing water availability and demand in the event of climate change.

Additionally, it is critical to know the efforts that are being made in the region to collect data and its completeness so that stakeholders can determine whether or not there are any additional necessary steps required to plan effectively.

Impacts that are currently mostly known are on surface water since little work has been done to model potential effects of climate change on groundwater resources. Therefore, there is a need to know the extent of supplies of groundwater in the region if they will have to be considered an option to supplement scarce surface water in the event climate change diminishes the latter. Before doing so, however, it would be critical to find out if the groundwater resources themselves will be affected by climate change. With regard to wetland resources, the question that stakeholders might wish to debate is whether current knowledge of wetland goods and resources is adequate and accurate for wetland planning purposes or more work needs to be done in this area. Experience for modelling of vulnerability of sectors to climate change impacts is currently with a few research institutes and NGOs, so the challenge is to impart the knowledge to water planners in government and water authorities.

6.2 Ecosystem-based Approach and Community-based Natural Resources Management

Considering the interactions among plant and animal life in utilization of water and wetlands, it is important that stakeholders consider a holistic approach to ensure effective water and wetlands management. Apart from the anticipated shortfalls in water supply as a result of reduced precipitation and increased evaporation, land-use activities can also exacerbate water scarcity in the region through land degradation thereby creating other physical, chemical, and biological factors that disturb the quantity and quality of water. An ecosystem-based approach (Table 12) moves away from a single resource or the traditional and sectoral management to a wider perspective that takes into account all the natural resources in an ecosystem like a wetland. Furthermore, the ecosystem-based approach attempts to regulate the use of ecosystems so that communities can benefit from them while at the same time minimizing the impacts on them so that basic functions are preserved. In other words, use the ecosystems, but don't lose them. This notion has been incorporated in a number of international conventions and reviews concerning environment and development, including the Convention on Biological Diversity (Pirot et al. 2000).

Table 12: Principles of the Ecosystem-based Approach

Principle 1:	The objectives of management of land, water and living resources are a matter of societal choice.
Principle 2:	Management should be decentralised to the lowest appropriate level.
Principle 3:	Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.
Principle 4:	Recognising 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:
Reduce those	market distortions that adversely affect biological diversity; align incentives to promote biodiversity conservation and sustainable use; internalise costs and benefits in the given ecosystem to the extent feasible.
Principle 5:	Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.
Principle 6:	Ecosystems must be managed within the limits of their functioning.
Principle 7:	The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.
Principle 8:	Recognising the varying temporal scales and lag-effects that characterise ecosystem processes, objectives for ecosystem management should be set for the long term.
Principle 9:	Management must recognise that change is inevitable.
Principle 10:	The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.
Principle 11:	The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
Principle 12:	The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Source: Masundire, 2000

While the ecosystem-based approach is being viewed as a potential panacea for resolving ecological problems, it has, however, not been thoroughly tested, least of all in Southern Africa. The challenge for stakeholders, therefore, is to test this approach by translating its principles into reality involving all sectors and segments of society. Most important of all, it is essential to determine whether or not the necessary information for an ecosystem-based management is available and understood. Adoption of ecosystem approach to water and wetlands management will require decision makers to have skills for organization and apply the concept probably through pilot projects to assess the activities and benefits, which can be realized from the approach.

A related approach that is considered effective for natural resources management is the community based natural resources management (CBNRM), which is known to have functioned well for wildlife management in the region (IUCN, 2001). What remains to be seen, however, is whether or not it can be effective for water and wetlands management. This being the case, there is a need for dialogue firstly to ascertain if CBNRM should be the route for water and wetlands resources management. Secondly, it is necessary to find out if communities have the necessary skills to apply this approach. If communities are to be involved in water and wetlands resource management, then they will need skills for resource conservation and entrepreneurship and past CBNRM activities reveal that skills in these areas are lacking.

6.3 Water-supply Options

Drought spells have prompted countries to implement water supply and demand measures. Among the water supply measures were building more dams and reservoirs, inter-basin transfers e.g. the Lesotho Highlands Water Project (Box 1), planning long water pipelines, and to a small extent water reclamation and recycling. The Lesotho Highlands Water Treaty was signed by Lesotho and South Africa as far back as 1986.. It is one of the world's largest engineering and water development project and the largest in southern Africa (Matlosa, 2000). The goals of the project are to: transfer water from Senqu River in Lesotho to the Gauteng Province via the Vaal River system; generate hydropower for Lesotho; raise money from sale of water to South Africa and promote economic development in Lesotho itself

The construction of the project started in 1988 and the entire project after its four phases will costs USD 8 billion which is 800% of Lesotho's GDP. The project has completed its Phase IA in 1995 and 72MW has become available to Lesotho. It has been indicated that Lesotho was getting R100 million annually from sale of water (Zhou, 2000). The true socio-economic impacts of the project are still to be fully grasped since the project did not go through an EIA (Matlosa, 2000).

Some of the adaptive measures presented in National Communications by some countries in the region (DEAT, 2000- South Africa, United Republic of Tanzania, 2000 and Ministry of Mines, Environment and Tourism- Zimbabwe, 1997 and Ministry of Works, Transport and Communication- Botswana, 2001) are increasing water storage facilities, including rain harvesting so as to maximize on the reduced runoff.

The point of concern, however, is the extent to, and costs at, which these measures could increase water availability and supply to users and its cost. Besides, it would be prudent to find out what impacts, be they negative or positive, these measures could bring to the region. As such, it would be worthwhile to assess if there are other measures that have not been considered or used adequately.

In dealing with effects of climate variability in the past, Southern African countries have resorted to technical strategies such as water rationing and preventing use of hosepipes for gardening in years of drought. In a few cases, countries in the region are employing fiscal measures like water pricing and demand management tools, e.g. prepaid meters as done in some parts of South Africa. There is a need, therefore, to evaluate possibilities for increasing efficient use of water and curb any rise in unnecessary demand by assessing its potential among the large water users such as irrigation. There may also be isolated cases of best practices of water demand management in the region. It would, therefore, be useful to know how refined and documented these water demand measures are for purposes of further adoption in the region.

The SADC region has several relevant initiatives in the water and environment sectors. It would be appropriate, therefore, for stakeholders to assess the extent to which the Revised SADC Protocol on Shared Watercourses (2000) and the created basin institutions can address the impacts of climate change on water and wetland management. It would also be important to assess what lessons could be drawn from notable initiatives such as the Zambezi Action Plan (ZACPLAN)- (Zhou, 2000) and how good lessons and experiences could be replicated in the region.

6.4 Policies and Legislation

Among the relevant international conventions and protocol on water and wetlands resources sector is the Ramsar Convention which specifically targets proper conservation and wise-use of wetlands. Table 3 has shown that 6 out of the 11 countries are parties to the convention and yet none has a wetland policy. Similarly for water, 6 have national water policies and only 3 have master plans. What remains to be known is how this situation has affected the water and wetlands management in the region and the modalities for propping member states to integrate regional and international agreements into national policies and legislation. Where policies and legislations exist, stakeholders ought to assess their adequacy in water and wetlands management, and to what extent they are being implemented as designed.

6.5 Insurance

To protect capital equipment or goods and services, it is customary to insure against any likely damages, yet this has not been the case with infrastructure, services, and goods in water and wetlands. Whether insurance companies will insure against damage caused by natural disasters remains to be known, but it is a matter that could be investigated by stakeholders as part of the dialogue. Capacity for valuation of wetland functions, goods and services considered necessary for decision-making and policy-making is lacking in the region. The dialogue would also need to consider valuation methods (e.g. willingness to pay) that can be applied in determining the value of wetland goods and services for insurance purposes.

6.6 Early Warning and Disaster Preparedness

In early-warning systems, data are communicated to decision makers and implementers timely so that impacts can be minimized. Although the 1994/95 season had deficient rains that were just as severe as that in 1991/92 in some cases, the early warning from the Drought Monitoring Centre (DMC) minimized the food importation bill and allowed an orderly and timely grain distribution (Garanganga, Internal Report; Harare Office). The region should, therefore, consider whether there is a need for new early-warning systems for water and wetlands or simply adapt the existing ones to cater for climatic change impacts on water and wetlands. Furthermore, it would be necessary to determine the target groups for such early-warning systems.

Various water and wetlands stakeholders that can be involved in the dialogue are presented in Table 13. The list is flexible; hence there is room for including more stakeholders or excluding others depending on the issues being addressed.

Table 13: Water and wetlands Stakeholders to Dialogue and Implement the Proposed Strategies.

Type of Institution	Role of Stakeholders
SADC-Water and ELMS	Regional Coordination
National Meteorological Services Departments	Source of Climatic data and monitoring
National Hydrological/Hydro geological Departments	Source of hydrological & hydrogeological data and monitoring
Ministry of Environment	Natural Resources Management & environmental issues
National Disaster Organizations	Disaster Preparedness
Research Institutes –e.g. University of Dare salaam for the FRIEND Project	Project developments and management
Water Commissions e.g. HYCOS	Project Management and capacity building
Urban and Rural Authorities	Water supply and demand issues
Water Authorities- National & regional e.g. Lesotho Highlands Project authority	Water supply and Management issues
Farmers	Irrigation consumption
Business Associations	Industrial/business consumers
Consumer Organizations	Consumer rights
Drought Monitoring Centre	Early Warning
NGOs (local, international, civic, gender)	Community education and facilitation roles
Donors/Multilateral Agencies e.g. UNDP	Funding
Water/environmental lawyers (Govt./private)	Legal issues
Insurance Representative	Insurance for infrastructure
Consultants	Resource persons

Known regular and active participants on water and wetland issues, from these organizations, should be solicited to attend the dialogue sessions on inter-linkages on water and wetlands and climate change. Such stakeholders will be able to share information on what has already been done and what is not being done in order to facilitate complementarity rather than 'reinventing the wheel'.

What is apparent now is that climate change issues have mostly been dealt with at research level by research institutes, NGOs, and consultants on behalf of governments in the preparation of their National Communications. To date only Zimbabwe, Lesotho and Botswana in the region have officially submitted their first National Communications to the UNFCCC. For the other countries, the reports are either in draft form (e.g. for South Africa, Tanzania and Mozambique) or are being prepared. Even where National Communications exist, recommended adaptation measures are not yet reflected in National Development Plans where they can get the necessary attention for implementation. It is necessary to determine the extent to which the adaptation measures proposed or employed in such previous studies could be feasible. If necessary, there might be a need to adopt them.

During floods, the recent strategy has been to open floodgates of reservoirs such as the Kariba Dam and that has exacerbated flooding downstream. Areas of investigation for stakeholders, therefore, include how to maintain uniform flows in regional watercourses and how to divert floodwaters to specialized reservoirs as a way of minimizing their severity particularly in downstream states. Disaster preparedness institutions require further empowerment to deal with large-scale disasters and to combine post-disaster with pre-disaster measures.

7 MECHANISMS FOR PROMOTING AND FINANCING RESILIENCE OF WATER AND WETLANDS

Financing is important to consider in the implementation of any strategies. Past coverage of analysis of vulnerability to water resources was limited by the sizes of the project finances provided by bilateral and multi-lateral agencies. While donors have been the major source of funding for water and wetlands projects and SOEs in the region, the dilemma is that some programmes cannot be sustained once donors phase out funding of projects. For example, as donors move out of Botswana some programmes are left without funding. The Forestry Association of Botswana may in future operate on a voluntary basis after DANCED withdrew its funding owing to the change in Government in Denmark. The forestry educational programme which was funded by NORAD also had eventually to be funded by GEF after the former withdrew its funding when Botswana was rated as an Upper Middle Income country. The NGO capacity building (NGO Support) Programme which was being supported by Dutch (HIVOS) also could not continue when the donor pulled out for the same reason. The challenge, therefore, lies in the creation of a sustainable financing mechanism for water and wetlands management in the light of such possible donor mobility. This being the case, it is incumbent upon regional governments and their private sectors to create such sustainable funding for monitoring and addressing impacts of climate change on water and wetlands.

A potential source of sustainable funding mechanism could be the New Partnership for Africa's Development (NEPAD), which is a pledge by African leaders, based on a common vision and a firm and shared conviction, that they have a pressing duty to eradicate poverty and to place their countries, both individually and collectively, on a path of sustainable growth and development, and at the same time to participate actively in the world economy and body politic (Anon. 2001). The NEPAD has a four-pronged strategy for financial resource mobilisation, i.e. increasing domestic resource, debt relief, Overseas Development Assistance reforms, and the private capital flows. Various activities have been outlined on how to achieve this strategy in order to ensure that resources are mobilised for the NEPAD. Should funding become available under the NEPAD, then it would be tapped for purposes of financing mitigation and adaptation measures against climate change impacts.

In addition to the initiatives described in the preceding paragraph, the UNFCCC has several financing mechanisms that are specifically designed to fund adaptation to climate change impacts, e.g. the Capacity Building Fund under Article 3 and Article 4 of the Convention (UNEP/IUC, 1999a) and the Adaptation Fund under the Clean Development Mechanism (Article 12 of the Kyoto Protocol- UNEP/IUC, 1999b). The Global Environment Facility also has capacity-building portfolios and it can fund issues of shared/international waters. Stakeholders have the task of investigating how to tap into these funds for purposes of alleviating impacts of climate change on water and wetlands in the region.

8 CONCLUSION

This paper set out to summarize salient points depicting the interrelationships between water, wetlands, and climate change in order to initiate the much needed dialogue. To this end, it presents the inter-linkages between climate change, water and wetlands as derived from reviews of such information in the region. The paper has also highlighted the importance of water and wetlands to development and maintaining ecological balance.

It is evident from the paper that impacts of climate change on water and wetland resources are expected to be worse than already experienced during the past climatic variabilities. Southern Africa is predicted to be warmer and drier than the severe droughts of 1991-1995. Such a scenario will have implications for water resources availability and supply, food security, health, and infrastructure. This situation calls for the water and wetlands stakeholders to mobilize strategies in order to identify adaptation measures to counteract impacts of climate change.

With respect to the state of knowledge of climate change impacts, the paper recommends that consideration should be given to available relevant information and on-going data collection activities in designing surveys for additional data. It has also suggested that capacity-building initiatives should focus on reliable assessment of impacts, adoption of new approaches to water and wetlands resource management, and strengthening disaster preparedness institutions so that they are in a position to deal with both pre and post disaster occurrences. A number of financing mechanisms for implementing the strategies have been proposed, and emphasis has been placed on making the source locally sustainable with additional support from UNFCCC portfolios and the NEPAD initiative.

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