Documentation of Research on Climate Change and Human Health in Southern Africa

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ENRECA HEALTH
danish research network for international health

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LIST OF ACRONYMS

AR4	IPCC Fourth Assessment Report
CC	Climate Change
DALYs	Disability Adjusted life years
DDRN	Danish Development Research Network
DRC	Democratic Republic of Congo
DWF	Danish Water Forum
ENRECA	Danish Research Network for International Health
ENSO	El Nino-Southern Oscillation
EU	European Union
FAR	IPCC First Assessment Report
GCMs	General Circulation Models
GDP	Gross Domestic Product
GHGs	Green house gases
HDI	Human Development Indices
HOORC	Harry Oppenheimer Okavango Research Centre
ITC	Inter-Tropical Convergence Zone
KCS	Kalahari Conservation Society
LDCs	Least Developed countries
NAPA	National Adaptation Programme of Action
MDGs	Millennium Development Goals
OAU	Organization of African Unity
IPCC	Intergovernmental Panel on Climate Change
UNFCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme
RCM	Regional Climate Models
SRES	Special Report Emissions Scenarios
SSA	Sub-Saharan Africa
SADC	Southern Africa Development Community
SPM	Summary for Policy Makers
SSTs	Sea surface temperatures
TAR	IPCC Third Assessment Report
WGI	Working Group 1
WGIII	Working Group III
WHR	World Health Report
WHO	World Health Organization
WMO	World Meteorological Organisation
SAR	IPCC Second Assessment Report

1.0 EXECUTIVE SUMMARY

1.1 Background

This report is a result of the effort made by three Danida supported Danish Research Networks: Danish Development Research Network (DDRN), Danish Water Forum (DWF) and the Danish Research Network for International Health (ENRECA Health) in collaboration with DBL- Centre for Health Research and Development (Faculty of Life Sciences, University of Copenhagen), the Harry Oppenheimer Okavango Research Centre (HOORC), Kalahari Conservation Society (KCS), Global Water Partnership SADC, Council for Scientific and Industrial Research (CSIR) and Ministry of Energy and Water, Zambia initiative to promote the idea of establishing a knowledge sharing and research network in the Southern Africa Development Community (SADC) region with special reference to climate change and health, water and food security. This report which focuses on climate change and human health in the SADC region is one of the three reports that were prepared under this initiative. The other two are on climate change and food security and climate change and water.

This study was commissioned to map out research results and key institutions in the SADC region where work on climate change and human health is being carried out or was carried out in the past. A desk study approach largely relying on information obtained through internet searches, electronic University of Botswana library resources and conference proceedings collected from various sources was adopted. In establishing an overview of existing knowledge and outcome of research projects regarding climate change and human health in the SADC region, the IPCC reports were valuable since each of these reports represented a thorough assessment of what is known on the subject matter over a certain interval since 1990. To supplement these sources of information, personal contacts were requested to provide certain information.

The basis of the report is that a healthy population provides the required labour force for development and reduces the dependence ratio of a population resulting in economic growth. On the other hand a strong economy is able to invest in health thereby improving the population health status.

1.2 Climate change in Southern Africa

Observations show that the SADC region is warming up. There has been an increasing trend in the number of warm spells and a decrease in the extremely cold days. Rainfall trends are variable but evidence point to an increased inter-annual variability in the post-1970 period as shown by an increase in extremely wet periods and more intense droughts in different countries.

Future projections show that changes will not be uniform over the region. The central southern land mass extending over Botswana, parts of north western South Africa, Namibia and Zimbabwe are likely to experience the greatest warming; 0.2°C to 0.5°C per decade. Most of this area is also likely to experience more intense droughts linked to changes in ENSO patterns. While parts of region lying towards the east may experience an increase in rainfall. However, the SADC region as a whole may experience delayed onset of rainfall and reduced growing season rainfall with periods of more intense rainfall

events leading to floods. Warming may also increase the intensity of tropical storms in the Indian Ocean.

The observed and projected warming, increase in rainfall variability and extreme events are creating environmental conditions that will alter the ecology and transmission patterns of climate sensitive infectious diseases and also negatively affect water supply and food production with consequences on human health in the region.

1.3 Status of human health in Southern Africa

Africa carries 25% of the world's disease burden and yet it has 1% of the world's economic resource (Clarke, 2008). The SADC health status is best assessed within Africa's vicious cycle where the proportion of both the healthy population and investment in health are minima i.e. less than 15% GDP for investment in health as agreed in the Abuja Declaration (OAU/SRS/ABUJA/3, 2001). SADC countries have huge resource constrain that limit ability to address the growing health challenges that the region is facing. Seven of Africa's 33 LDCs are among the 15 SADC states. The world's highest prevalence of HIV are found in southern Africa (Botswana, 23.9%; Lesotho, 23.2%; Swaziland, 26%; Zimbabwe, 18%). Malaria and tuberculosis continue to be major killers in the region. Schistosomiasis and soil transmitted helminthes are at levels considered to be of public health importance.

Due to environmental changes, occupational exposures, change in diet and lifestyles, non-communicable diseases such as cancer, sugar diabetes, cardiovascular disease are also increasing in southern Africa. This is made worse by widespread nutritional disorders mainly due to poverty and lack of education. The SADC region is therefore double burdened by both infectious and rising non communicable diseases. The low health status of the region is exacerbated by, among other factors, poor public health practices, inadequate infrastructure, poor waste management practices and poor governance, rapid population growth and mobility, land use change as well as growing change in climatic conditions.

1.4 Mapping of studies on climate change and human health

The inventory of work showed that while there has been growing concern on linkages between climate change and human health globally specific work linking climate change and health in Africa remains limited... Among the little that has been done slightly more work was carried out in east Africa than in southern Africa. As a result very few institutions specializing in climate change and health were identified in the SADC region mainly in South Africa which was found to be the only country with a huge database of institutions working on climate change. Most institutions work on cross cutting issues of climate change with the majority of them focusing on adaptation. This bias towards adaptation can be linked to the evidence from the IPCC reports that point to the fact that the climate system has already been affected i.e. even if green house gas emissions were significantly reduced impacts will continue into the next 100 years or so. It is therefore logical to prepare populations for the inevitable adverse conditions. Evidence on impacts of climate variability and climate change seems to have been more documented in the agricultural and water sector where most institutions working on climate change are found. A close look at the National Adaptation Programmes of Action (NAPAs) for LDCs prepared with support of UNFCCC clearly shows that health has not been prioritized. Out of the 7 LDCs in SADC only Madagascar, Zambia and Tanzania

presented projects on health while the remaining 4, namely DRC, Lesotho, Malawi and Mozambique did not field any projects on health.

Much of the work on climate change is done through networks. In fact there are more networks than institutions that are conducting work on climate change. A total of 36 networks were identified and it must be noted that the list is not exhaustive. Many networks including African Technology Policy System (ATPS), Capacity Strengthening of Least Developed Countries on Climate Change Adaptation (CLACC), ZERO Zimbabwe, CARE Zimbabwe, Global Network on Climate Change in Africa (in the process of being formed), African Climate Change Fellowship Programme (ACCFP) Climate Change Adaptation in Africa (CCAA) and the current initiative involving Danish networked institutions and southern institutions have indicated some commitment to conduct institutional mapping but this work is still to be done.

Despite the considerable large networks working on climate change, there is limited published work on climate change and human health in the SADC region. This probably indicates the difficulty in sourcing research funds to support laboratories that can carry out such work. The few studies being conducted in the region are usually based on collaboration between scientists in the region and northern partners.

1.5 Linkages between climate change human health, water and food security

Outputs from the limited work available show that environmental conditions have play a significant role in human health in the SADC region. Climate sensitive, parasitic infections such as malaria; schistosomiasis; trypanosomiasis; leishmaniasis and intestinal helminths and other climate linked epidemics such as cholera, diarrhoeal infections are common in southern Africa although malaria is currently the number one killer. Climate change will alter the ecology and transmission patterns of these infectious diseases through change in rainfall, temperature and humidity although this will depend on the type of disease, locality and socio-economic conditions. More specifically impacts of climate change on key environmentally sensitive sectors such as water and food production will have a bearing on human health.

An analysis of potential impacts of climate change on water and food production shows that climate change impacts will result in complex interactions that will compromise human health. Southern Africa is a region already facing water shortages which will be exacerbated by climate change. Water shortages during e.g. drought will compromise hygiene but exceptionally wet periods may result in contaminated water supply systems and as a result both conditions have a potential to lead to outbreaks of water-borne diseases such as cholera, intestinal worms and typhoid. Of major concern currently is the possibility for exceptionally wet periods to lead to the spread of malaria range beyond its normal zone into population that has low immunity as has been observed in the highlands of Zimbabwe. In coastal areas, rising sea surface temperature may increase conditions for cholera outbreaks.

Increased climate variability will increase risk in agricultural production. Change in ocean currents due to warming and sea level rise will negatively affect coastal marine fisheries and reduced output from inland fisheries is also likely due to decline in surface water accelerated high evapo-transpiration and land degradation. Climate change is therefore likely to result in reduced food security in the region leading to widespread malnutrition

and which will increase vulnerability to diseases. Loss of productivity of land will drive people to cities where already inadequate provision of sanitation facilities is compromising health. Coastal areas could face complex health problems linked to sea level rise resulting in reduced fresh water supply and loss of agricultural land... Added to these factors is how climate change induced poor human wellbeing will interact with complications linked to the spread of HIV/AIDS in the region. All these inferences made from combined pieces of evidence need to be validated through an integrated and sustained climate change and human heath regional research programme.

1.6 Conclusions

Much of the inferences made regarding impacts of climate change in Africa, particularly with regard to health, are based on scanty data. Assessment of the status of health in Sub-Saharan Africa (SSA) showed that the region is overburdened by diseases, the economies are generally stagnant and in some cases declining with exception to few countries and the health systems are gradually being weakened by among others brain drain. It is evident that SSA is overly vulnerable to impacts of climate change mainly in the agricultural and water sectors that have serious bearing on the population health status. While there is growing evidence, globally, on climate change and human health with particular reference to climate sensitive diseases like diarrhoeal diseases, dengue (Arthropod borne fever), malaria, schistosomiasis, trypanosomiasis and under-nutrition and others, limited work on these linkages has been conducted or is ongoing in the SADC region. For example the resurgence of malaria has been linked more strongly to socio-economic issues including drug-resistance than to climate change indicating the need to investigate each case.

Indirect effects of climate change on diseases for instance through socio-economic responses to changes in climate leading to increasingly favourable conditions for the spread of these diseases are not emphasized in most studies. Such responses include increased migration to cities leading to congestion and shortages of critical facilities that increases the spread of flood induced diseases such as cholera and diarrhoea or exposure of more people to HIV/AIDS infection thus making them more vulnerable to climate driven diseases. A more integrated approach to human health and climate related diseases is thus required.

Assessing climate sensitive diseases for national policy needs is greatly constrained by the difficulty, at smaller scales where natural climate variability is relatively larger, to reliably simulate and attribute observed temperature changes. Nonetheless, some studies like one in Botswana have demonstrated the link between malaria outbreak and seasonal climatic factors and made it possible to develop early warning preventive measures.

Many climate change networks are operating within southern Africa but they seem to be working in isolation and information on their activities is not readily available.

1.7 Research gaps and recommendations

There is need for more work on climate change and human health based on collaboration among SADC scientists and with their south and northern partners. Such collaborations need to be geared towards building local capacity. Such collaborations need to be accompanied by sustainable mechanisms of supporting research on climate change and human health for instance through provision of equipped institutions of excellence at the

national level and this could be achieved through cooperation between national Government and international development Agencies.

Understanding climate change and human health requires locally relevant knowledge on environment in general and on climate change. Information that is currently available, particularly with respect to climate change is at a broad scale making it difficult to use for policy formulation. As a result the following research areas have been recommended from findings of this study:

- Work on modelling possible changes in tropical cyclones affecting the southeast coast of Africa and the implication on human health is needed for the SADC region.
- Further research is required on how patterns of ENSO may change with increasing warming and the implications of this on future climate variability and health in Southern Africa.
- Although relatively better understanding of malaria exists, more work needs to be done particularly on monitoring the infection in terms of both climatic and socio-economic factors as well as population mobility.
- Research focused on climate change and socio-economic factors affecting the transmission and control of schistosomiasis, intestinal helminths and meningococcal meningitis diseases will contribute to improved health in the region.
- Also essential in the long run is monitoring and developing early warning systems for these diseases as well as others such as cholera, diarrhoeal infections to help build and implement a policy of disease prevention in the SADC region.
- Investigations on psycho-social disorders that emanate from exposure to extreme events such as severe drought or flooding leading to loss of production capacity, family and displacement will provide valuable information required in the post disaster rehabilitation period.
- Better understanding of how climate change stresses might influence the link between health problems due to climate sensitive diseases and HIV/AIDs is critical for the SADC region which is the most affected by the HIV/AIDS pandemic In Africa.
- Investigations are also required on how climate change induced diseases might affect food production and feedbacks on health in the long run.
- Treated effluent water for irrigation and other non-domestic uses is increasingly becoming necessary in view of the anticipated decrease in rainfall in southern Africa. Thus, the importance of understanding the implications to human health of using such water cannot be underscored.

In addition to the above there is need to establish networks to motivate, rally policy makers and share knowledge over these pertinent but neglected issues and provide linkages to scientists abroad. Establishing and running such networks requires resources and therefore support from international organisations and developed countries is much needed at the initial stages.

1.8 Way forward

This study has shown that no network or institution in the SADC region is specifically addressing linkages between climate change and health. It is therefore important that such a network be established. The proposed network should also address environmental health in general with an initial emphasis on linkages between climate change, water and food

security. Given that there are already many networks within the region, efforts should be made to collaborate with those networks in order to avoid duplication of activities.

2.0 INTRODUCTION

2.1 Background

The phenomenon of Climate Change (CC) is a reality that is now universally acknowledged and better understood than it was in 1988 when the Intergovernmental Panel on Climate Change (IPCC) was formed by the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP). IPCC was mandated to review all work on climate change and provide comprehensive and peer reviewed information that can be used to guide policy makers to address global warming and climate change. IPCC is formed by three working groups: Working Group I (WGI) - the physical basis of climate change; Working Group II (WGII) - Impacts of, vulnerability and adaptation to climate change and Working Group III (WGIII) – mitigation and in addition a task force on green house gas inventories. The first report of the IPCC served as a basis for the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) which came into force in 1994 and has grown to a membership of 189 parties. At its 28th Session, the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) recognized the role of climate change regional centers and networks in enhancing adaptation to CC; and encouraged the establishment of new networks. Consequently, many networks have been formed in the past few years. Global and regional (Africa, Asia, Europe and America) networks for Climate Change Adaptation are concurrently being established through the efforts of UNEP.

The mounting evidence on climate change show that changes in global average temperatures, rainfall patterns, widespread melting of snow and ice, and rising sea levels are affecting all aspect of human livelihood systems through for instance, changes in water quality and supply, food production, ecosystem resources, and changes to human settlements and health. Developing countries are feeling these changes acutely and are projected to suffer disproportionately from future climate changes and variability. This is primarily because these countries rely heavily on climate-sensitive sectors, tend to be located in marginalized areas susceptible to extreme events and already face huge gaps in infrastructural development, human resources and technological capacity, which constrain their integration into the global economy, locking them under perpetual vulnerability to both socio-economic and climate linked stresses.

Detailed and context specific knowledge of the consequences of climate change at global, regional, national and local levels is vital particularly for developing regions, to use to overcome the negative effects of climate change, secure the most needed and efficient adaptation to climate change and facilitate access of information to policy-makers and development practitioners. However, much of the inferences made regarding impacts of climate change in Africa in particular are based on scanty data and sharing of such information has not happened in a systematic manner. It is this realization that made the three Danish Networks: Danish Development Research Network (DDRN), Danish Water Forum (DWF), and the Danish Research Network for International Health (ENRECA Health) in collaboration with DBL-Centre for Health Research and Development (Faculty of Life Sciences, University of Copenhagen), the Harry Oppenheimer Okavango Research Centre (HOORC), Kalahari Conservation Society (KCS), Global Water

Partnership SADC, Council for Scientific and Industrial Research (CSIR) and Ministry of Energy and Water, Zambia to take an initiative to promote the idea of establishing a knowledge sharing and research network in the Southern Africa Development Community (SADC) region. This is in line with the ongoing UNFCCC initiatives to address climate change.

As part of the development process of the network, it was deemed necessary to commission a consultancy that documents research on climate change and human health, water and food security in the SADC region. The three themes; health, water and food security were considered to be the most important for the region based on the 2008 IPCC report. The findings of the consultancy were discussed at a Knowledge Sharing Workshop held in Cape Town 18-20th February 2009 where the idea of forming a SADC based network was discussed further with other stakeholders (researchers, development agencies and policy makers). A paper based on the three consultancy reports was presented at the Copenhagen International Congress on Climate Change in March 2009.

This study is concerned with climate change and human health in Southern Africa and the interaction of this with water and food security both of which are climate sensitive sectors. Because climate change is an environmental issue, the study therefore contributes to issues of human health and environment. The focus is on mapping research results, key institutions and networks in the field of climate change and human health in the SADC region to improve information sharing and identify gaps that need to be addressed. Specific objectives of the study drawn from the terms of reference (TOR) presented in Annex 1 are as follows:

- Providing an overview of existing knowledge and outcome of research projects regarding climate change and human health in the SADC region.
- Showing linkages between health, water and food security in the context of climate change
- Mapping of institutions within SADC working on climate change and health
- Identifying research and knowledge areas of common interest to researchers and development practitioners
- Making recommendations on 'gaps' and perspectives for future research collaboration areas

2.1.1 *Climate change at the Global scale*

IPCC has produced assessment reports every 5 years since 1990 which when take together show the build up evidence on climate change and human activity:

- The First Assessment Report (FAR) in 1990) concluded that there was insufficient observational evidence on climate change.
- In the Second Assessment Report (SAR) in1995 it was noted that 'the balance of evidence suggests a discernible human influence on global climate'
- The Third Assessment Report (TAR), 2001 acknowledged that most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations'
- While the Fourth assessment Report (AR4), 2007 made it clear that 'Warming of the climate system is unequivocal' (AR4WGI SPM, 2007).

The growing body of evidence on climate change show that human activity is altering the climate through the process of global warming resulting from an unprecedented accumulation of green house gases (GHGs) into the atmosphere (Alley, et al., 2007) (Box 1). Major GHGs include carbon dioxide (CO_2) mostly from fossil fuel and land-use change and methane (CH_4) and nitrous oxide (NO_2) from for example, agricultural activities (Nakicenovic et al., 2000). The atmospheric concentration of CO_2 increased from the pre-industrial value of ~ 280 ppm to 379 ppm in 2005 (AR4 WGI SPM, 2007). The major emitters are the developed countries and more recently the fast growing economies of China, India and Brazil (HDR 2007/2008, 2007; Gupta et al., 2007). Africa, accounted for 13.8% of the worlds' population by 2005 but contributed about 2.5% of the global cumulative CO_2 emissions from fossil fuel (Canadell et al., 2008; HDR 2007/2008, 2007).

In addition to the observed changes noted in Box 1, climate change projections based on global circulation models (GCM) point to continued warming into the future (Box 2) with more negative consequences on a wide ranging environmental processes that have a bearing on water supply, food security and health among others. This makes adaptation a priority in developing countries in particular where vulnerability is high.

2.1.2 *The case for Africa: An overview*

For the case of Africa both the third and fourth IPCC reports signal that large parts of the continent will become drier, with more variable rainfall than at present and this will be a major constrain to the course of sustainable development and the ability to meet the millennium development goals in most African countries.

The following areas within the environmental arena were identified as areas of major concern with respect to potential impacts of climate change in Africa (Desanker et al. 2001):

i. Water resources: Nearly 25% Africa's population currently experiences water stress (Boko et al., 2007). With increasing shortage of water shared basins may become areas of potential water conflicts.

ii. Food security: Food security is likely to decline due to the high risk of reduced agricultural production. Increased frequency of climate extremes i.e. high intensity rainfall events, flooding and drought will negatively affect food production. Coastal marine fisheries will be affected by change in ocean currents due to warming while inland fisheries will face problems of shortage of water.

Box 1. Some of the observed evidence of climate change at a scale global (AR4WGI SPM, 2007).

- The total global temperature increase from 1850 – 1899 to 2001 – 2005 period was 0.76^0C and eleven of the twelve years from 1995-2006 rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850).
- Widespread changes in extreme temperatures have been observed over the last 50 years. Cold days, nights and frost have become less frequent, while hot days and nights, and heat waves have become more frequent.
- Consistent with the extra water vapour that warmer air can hold, the average atmospheric water vapour content has increased since at least the 1980s over land and oceans as well as in the upper troposphere. And consistent with warming and observed increases of atmospheric water vapour, the frequency of heavy precipitation events has increased over most land areas.
- More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics.
- Average temperature of the global ocean has increased to depths of at least 3000 m since 1961 and the ocean has been absorbing more than 80% of the heat added to the climate system which causes seawater to expand, contributing to sea level rise
- Average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003. The total 20th century rise was estimated to be 0.17 m.
- An increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures.

Box 2. Some of the future climate change projections at global scale based on several models (AR4 WGI SPM, 2007).

- Due to the slow response of the oceans, further warming in the next two decades of about 0.1°C per decade is expected even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels.
- Thermal expansion would continue for many centuries, due to the time required to transport heat into the deep ocean. Thermal expansion alone would lead to 0.3 to 0.8 m of sea level rise by 2300 (relative to 1980–1999) if radiative forcing were to be stabilized in 2100 at A1B levels.
- The likelihood that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent during the 21st century is high.
- Continuing from the observed patterns high-latitudes are likely to experience increases in the amount of precipitation while the opposite is most likely in most subtropical land regions e.g. Africa with a decrease of up to about 20% in the A1B scenario by 2100.
- Future tropical cyclones (typhoons and hurricanes) are likely to become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs.

iii. Natural resources and biodiversity: The continent is likely to experience reduced availability of natural resources and irreversible loss of biodiversity that will be partly exacerbated by enhanced processes of land degradation and desertification due partly to increased land use pressure.

iv. Climate related diseases: An environment characterized by warming and rainfall extremes will change the occurrence and spatial patterns of vector- and water-borne diseases. Coastal zones could experience more frequent outbreaks of cholera epidemics due to more warm water. Human health will also be jeopardized by general degradation of resources, shortage of water and loss of agricultural productivity.

v. Coastal Zones: Increased exposure of coastal zones to sea-level rise will have dire consequence on fresh water supply, agricultural production and human infrastructure.

Impacts of climate change are a major challenge for Africa which is highly depended on climate sensitive environmental resources and is mostly formed by very weak economies with a large proportion of the population living under the poverty datum line of 1USD per day (Annex 2). In comparison to other regions Africa has the weakest economy with a total GDP per capita of 1 016 compared to 1 462 for Asia/Pacific region, 26 404 for Europe and 8 416 for South America. As a result it has been concluded that, Africa, which in 2005 had a population of over 880 million with a growth rate of 2.4%, twice the global mean, and houses two thirds of the Least Developing Countries (LDCs), is one of the most vulnerable continents to climate change (IPCC, 2001; 2007). The vulnerability of Africa to climate Change results from various interconnected factors noted in Annex 2 among which are poverty, accelerated degradation of resources, weak health institutions, conflicts and poor governance (Annex 2).

Impacts of climate change on human health in Africa will be both direct i.e. through temperature extremes, insufficient rainfall, physical impacts of floods but also indirectly through impacts on climate sensitive diseases, natural systems, agriculture, human infrastructure and the economy in general. Some of the likely impacts of climate change on health in Africa are summarized in Annex 3.

Health is an outcome of numerous interactive socio-economic and environmental factors and as a result it is best to use to demonstrate the vulnerability of Africa to climate change. Environment is a primary determinant of human health. Environmental threats to human health in Africa include degradation of ecosystems, lack of access to clean water and sanitation, air pollution etc. The first-ever Inter-ministerial Conference for Health and Environment in Africa held in Libreville, Gabon, in 2008 recognized the inter-linkages between environment and health in Africa, and their importance for sustainable development (http://www.unep.org/health-env/pdfs/Conference-background-ENG.pd). While Saunders et al. (2004) have provided a model that describes the importance of health as a determinant of development. A healthy population provides the required labour force for development, increases savings and investment for the country, and reduces the dependence ratio of a population resulting in economic growth. On the other hand a strong economy is able to invest in health thereby improving the population health status. At a global scale there has been an improvement in health in the past 50 years (World Health Report, 2008). For example, people are generally wealthier and live longer than 30 years ago. But this is not the case for Africa.
Africa is caught up in a vicious cycle where the inputs to the Saunders model are minimal. Investment in health is generally weak with the majority of countries failing to avail the 15% GDP for investment in health as agreed in the Abuja Declaration (OAU/SRS/ABUJA/3, 2001). Africa remains the continent with the highest neonatal mortality rate (43 deaths per 100 000 live births) among the WHO Regions (Fig. 1). The

most developed regions, Europe and America have neonatal rates as low as 11 and 12 deaths per 100 000 live births, respectively. The main causes of neonatal deaths (expressed as a percentage of the total causes) across all regions are severe infections (27%), birth asphyxia (24%), preterm births (23%) neonatal tetanus (9%), congenital anomalies (6%) and other conditions (11%).

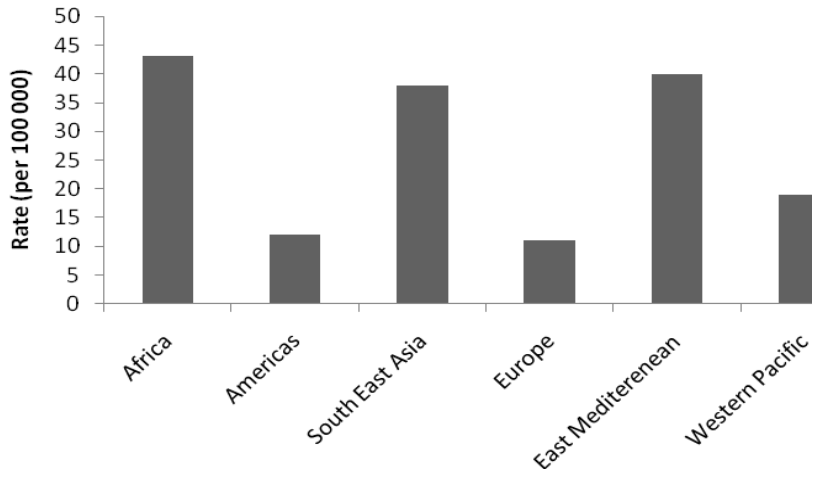

Figure 1. Neonatal mortality rates (per 100 000) for WHO regions.
Source: Adopted from World Health Report of 2008

The gains in population health made in the last millennium have, in most cases, been reversed by the HIV/AIDS pandemic, malaria and tuberculosis which are responsible for the deaths of three million people per year in Africa (Annex 2). Sub-Saharan Africa (SSA) has the highest number of people living with HIV (Fig. 2). The situation has been compounded further by the re-emergence of tuberculosis.

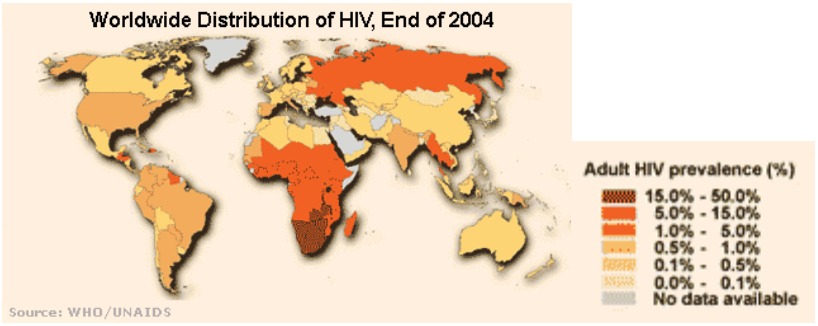

Figure 2. World distribution of HIV by end of 2004.
Source: WHO/UNAIDS

The economic implications of AIDS and malaria are evident from the disability adjusted life years lost (DALYs) reported by WHO (WHO, 2004) and summarized in Table 1. Malaria accounts for about US$12 billion loss to the African continent's GDP annually and is huge burden to the already limited medical services (Boko et al., 2007).

Table 1. Burden of diseases in DALYs by cause and mortality stratum for children under five years of age and males aged 15-59 years in the African Region

Disease	Mortality stratum	
	High child, high adult (000)	**High child, very high adult (000)**
AIDS	14 620	49 343
Malaria	20 070	20 785
Respiratory infections	18 976	16 619
Perinatal conditions	10 869	10 485
Diarroea	11 548	11 689

Adopted from World Health Report 2008

Furthermore the SSA region has environmental conditions that are conducive for many disease transmitting vectors and pathogens. Access to safe water and adequate appropriate sanitation are key issues in the region. Figure 3 clearly shows that schistosomiasis is largely a problem of Africa. Soil transmitted helminths (STH) follow the same distribution pattern (Figure 4). While figure 5 shows that Africa leads the world with respect to malaria suitable areas. In the past decade SSA has experienced frequent floods (Cyclone Eline, 2000; Tsunami, 2007) and droughts that resulted in displacement of people and many deaths due to diseases caused by contaminated water or/and poor personal hygiene and malnutrition. Towns and cities have rapidly grown in terms of population but the capacity to provide adequate safe water and appropriate sanitation has not matched this growth leading to worsening health conditions

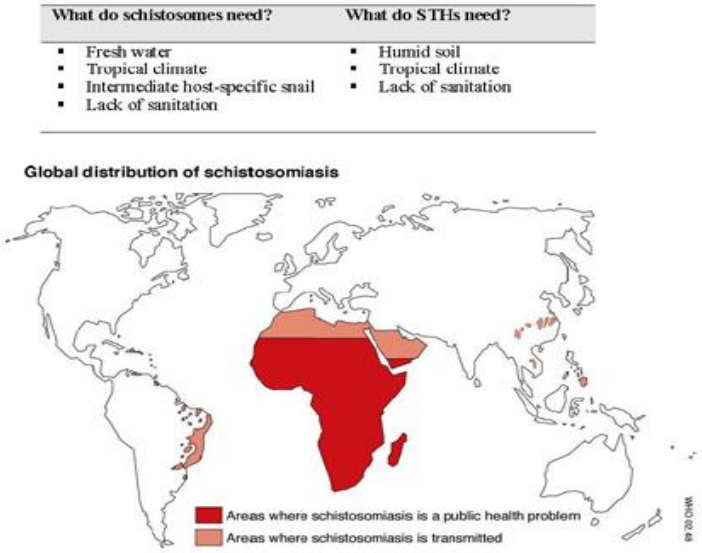

Figure. 3. Global distribution of schistosomiasis (WHO website)

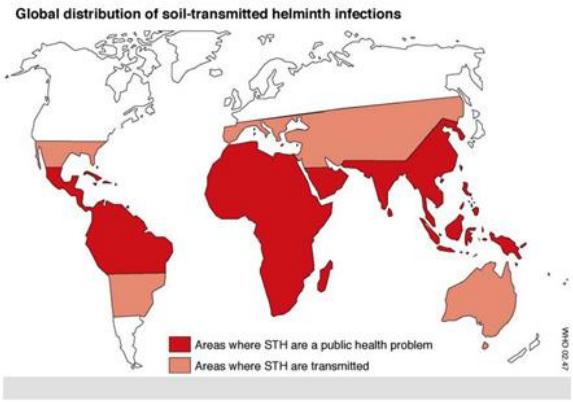

Figure 4. Global distribution of soil transmitted helminth infections (WHO website).

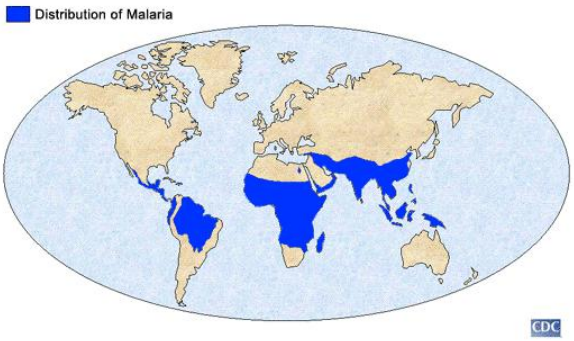

Figure 5. Global Distribution of Malaria.

Source: Centre for disease control and prevention

In addition, diseases of the poor classified by WHO as the neglected tropical diseases (NTD) are also found in tropical Africa. These include schistosomiasis and soil transmitted helminthes, Buruli ulcer, chagas disease (American trypanosomiasis), Dengue/dengue haemorrhagic fever, *dracunculiasis* (guinea-worm diseases), human African trypanosomiasis, leishmaniasis, leprosy, lymphatic filariasis, neglected zoonotic diseases, onchorcerciasis, trachoma and yaws. While that is so diseases and conditions that used to be associated with developed countries have now reached the public health importance level. These include cardiovascular diseases, obesity, under-nutrition, cancer, injuries, violence, blindness, genetic disorders and oral diseases. According to the WHO statistics these conditions account for 27% of Africa's total disease burden (WHO, 2008).

It can be concluded that a combination of the current poor health status of Africa, the prevalence of climate sensitive diseases, plus the widespread diseases of the poor (as classified by WHO) and the growing non-communicable disease clearly shows that the health sector in Africa will be highly vulnerable to the added stress of climate change. Adaptation to climate change in Africa needs to give greater priority to health.

2.2 Scope, Methods and Structure

Work presented in this report describes general issues of climate change as a way of contextualizing the main focus of linkages between climate change and human health. It

was, however, unavoidable to transcend into the themes of water and food security as these closely interact with the human health theme particularly so for SSA. Spatially, the study focussed on the SADC region in the context of the overall continental and global perspectives on human health, climate change and linkages with food security and water.

A desk study approach largely relying on information obtained through internet searches (key words: climate change (Also used were impacts, adaptation and vulnerability), health (in some cases using specific names of diseases), southern Africa (country names also used), networks, institutions, water and food production (also use specific food types e.g. fisheries, maize. Livestock etc)) at the University of Botswana electronic library resources and conference proceedings collected from various sources was adopted. In establishing an overview of existing knowledge and outcome of research projects regarding climate change and human health in the SADC region, the IPCC reports were very valuable since each of these reports represented a thorough assessment of what is known on the subject matter over a certain interval since 1990. To supplement these sources of information, personal contacts were requested to provide certain information. Participants' lists found in proceedings of various climate change meetings were also used to contact relevant participants. The letter sent to the identified participants requested them to send a summary of their climate change related activities, their institutional affiliations and details of their colleagues (outside their institutions) working on climate change. A similar letter was sent to people identified through individuals initially written to, thereby following a snowball approach.

This paper is organized into 9 main sections; executive summary, introduction, findings, synthesis, conclusions, research gaps and recommendations, way forward, references and annexes.

3.0 FINDINGS

3.1 The Status of Human Health, Climate, Food Security and Water Resources in Southern Africa.

3.1.1 *The climate of Southern Africa*

Southern Africa extends over an area of 6.93 million km^2 over which are the 14 countries of the Southern Africa Development Community (SADC) (Fig. 6). The climate of Southern Africa ranges from humid coastal zones to land-locked (semi-) arid lands with high intra-seasonal and inter-annual variability and to the humid tropical equatorial regions of DRC and parts of Angola. Inter-annual climate variability over much of Southern Africa is strongly influenced by El-Nino Southern Oscillation (ENSO) (Desanker et al., 2001). Severe droughts experienced have been linked to changes in regional atmospheric-oceanic anomalies before the 1970s and later to changes in ENSO patterns. Possible influences of increased temperature on patterns of ENSO and consequent implications on future climate variability in Southern Africa are not known.

Rainfall levels and patterns vary enormously but areas of unpredictable rainfall dominate the region. While drought is the most common climate extreme, floods also occur, for instance, the 1999/2000 devastating floods in Mozambique over the Limpopo basin. For most of the region rainfall occurs in summer between October and April. The Inter-

Tropical Convergence Zone (ITC) and the Atlantic Ocean Air masses result in higher rainfall in the northern parts, e.g. the mean annual rainfall of DRC is over 3000mm. The maritime air masses of the Indian Ocean are influential over the southern parts but their impact decreases westward. This combined with the effect of the cold Benguela current along the Namibia coast account for the semi-arid to arid conditions over much of the mid-southern part of the continent covered mostly by the Kalahari sands. Mean annual rainfall as low as 50mm over parts of Namibia and 250 mm on the western parts of Botswana are registered in this area (Botswana Ministry of Works, Transport and Communication, 2001).

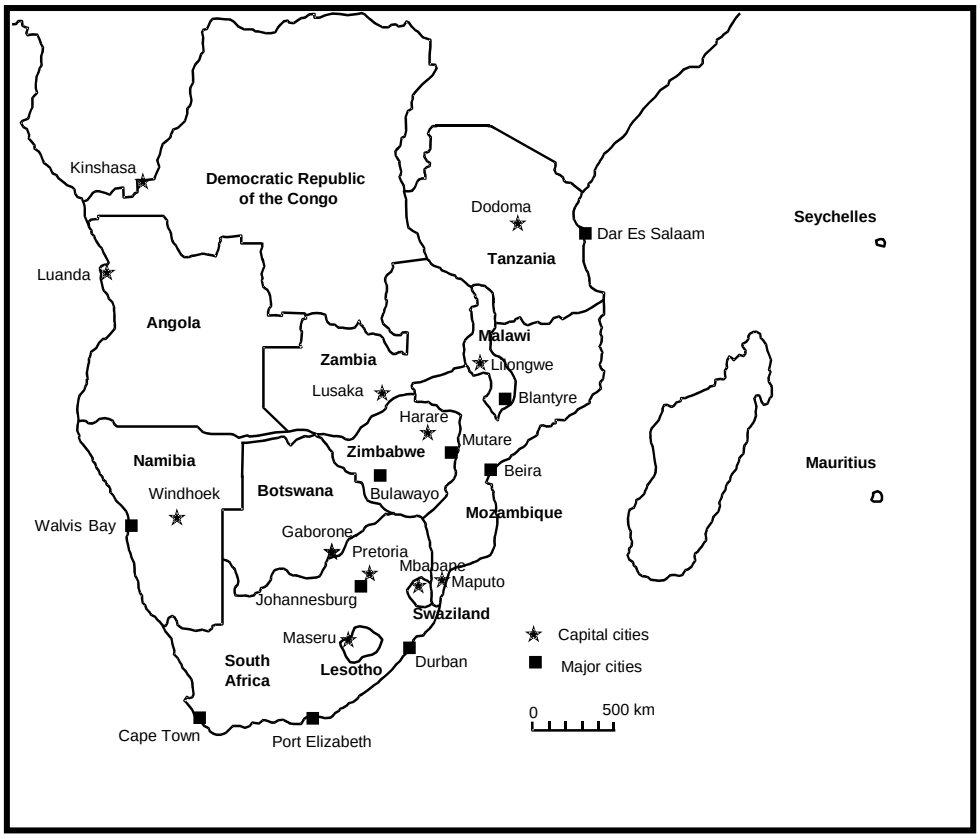

Figure 6. Map of Southern Africa

3.1.2 *Food resources*

Food availability, provision and access are important measures of health in any society. This section reflects on some of the environmental resources available in the region for food production. About 21% of the region is desert, mostly in parts of South Africa, Botswana and Namibia and with limited potential for food production (Scholes and Biggs, 2004). Food production is also constrained by the predominantly infertile soils derived from granite related rocks. Pockets of fertile soils are limited to drainage networks. The central parts of the region, stretching from the northern parts of South Africa to DRC are covered by the nutrient poor aeolion Kalahari sands (Scholes and Parsons, 1997).

Much of food security in the region relies on agricultural production (arable and pastoralism) although crop production is a high-risk activity in the drier parts of the subcontinent. A close analysis shows that the total potential agricultural area is heavily underutilized (Annex 4). Only 20% of the suitable land is under cultivation and irrigated agriculture is limited with exception to South Africa. For rural subsistence farmers in particular a diversity of livelihood sources (agriculture and non-agriculture activities) is adopted as a strategy to reduce risks and increase livelihood security (Dube and Sekhwela, 2007 and 2008). Southern Africa is rich in natural resources as shown by diverse plant and wildlife species which sustain the eco-tourism industry, food and medicinal needs of rural livelihoods. Forest in the SADC region covers about 33 % of the land surface (SADC/ESD, 2008). The region also has a large marine space, spanning from Tanzania on the Indian Ocean to Angola providing a variety of migratory fish stock such as pilchard, mackerel, hake, shrimp, tuna and others. Inland fisheries are also important for instance, over Lake Malawi and now commercial fish farming on Lake Kariba.

Environmental threats such as frequent drought, water shortages and increasing land degradation partly contribute to below average food outputs in the region. GECAFS. (2006) noted that "while population growth had slowed down from above 3% in the 1970s and 1980s to an average of 2.7% per annum in the 1990s, the increase remained above the growth rate of food production of only 2% per year." Attempts are made to address the net decline in per capita food production through imports and food aid, but in general majority do not have sufficient food, and nearly half the population are undernourished and this is a source of poor health condition (WHO, 2000).

3.1.3 *Water resources*

Water is a very important factor in human health both in terms of its quality and quantity for domestic use and food production. Five of the ten largest surface water bodies in sub-Saharan Africa occur in Southern Africa with basins extending from about 385 000 km^2 for Limpopo to 3720 000 km^2 for the Congo River (Sharma et al, 1996). But water is a scarce commodity in the region and most countries belong to shared basins. For example, seven out of the fourteen SADC countries belong to multiple international river basins, typically involving four to nine river basins per country which can be a source of conflict when supplies dwindle. In general the region can be divided into the water-scarce south and water-rich northern countries. The most developed countries, also found in the south; Botswana, South Africa, Namibia and Zimbabwe are the most water stressed (Dube, 2003).

Water supply is also threatened by a number of negative environmental processes experienced in the region. Widespread land degradation leads to high siltation of tributaries feeding into large rivers and also water reservoirs which reduce infiltration rates, and increases the probability of flooding in wet periods. Estimates of the rate of deforestation in the region are variable, 0.1-0.7% (Scholes and Biggs, 2004) but Yirdaw (1996) put this to 0.9% per year in 1993. Ground water resources are fossil supplies and the current rate of recharge is far lower than the rate of extraction, estimated at 1% or less of the mean annual rainfall and much of the ground water is of poor quality (Scholes and Biggs, 2004). Treated effluent water offers important opportunities for irrigation but is only emerging and the health implications of using this source for irrigation and other uses in the region have not been investigated.

3.1.4 *Health status and diseases of Southern Africa*

The 14 SADC countries had an estimated population of 110,353,486 with an average growth rate of 2.8% per anum in 2002 which was higher than the average rate of growth for Africa, 2.4% per year and more than double the average world rate of 1.3% per year (SADC/ESD, 2008). Although there is great diversity among the SADC countries, overall the economy of the region has been declining (Table 2). Seven of these countries, namely Democratic Republic of Congo (DRC), Malawi, Tanzania, Madagascar, Mozambique, Zambia and Lesotho fall under the LDC category. The poor economic situation has led to declining investment in health as with the rest of Africa.

Table 2. SADC Human Development indices (HDI) based on United Nations Development Programme's Human Development Report of 2006 and Gross Domestic Product (GDP) based on World Bank statistics for 2008.

Country	HDI	GDP-per capita (USD)
South Africa	0.653	5 162
Angola	0.439	1 945
Democratic Republic of Congo	0.365	120
Tanzania	0.430	360
Mozambique	0.354	347
Botswana	0.570	5 712
Zimbabwe	*0.491	*2 395
Madagascar	0.509	320
Namibia	0.626	3 049
Mauritius	0.800	5 053
Zambia	0.407	636
Malawi	0.388	230
Swaziland	0.500	2 270
Lesotho	0.494	777

** = based on 2007 statistics*

Table 3 shows demographic indicators that further demonstrate inequities in health status across countries. In 2004 life expectancy ranged from 31.3 years (Swaziland) to 72.4 years (Mauritius), under five child mortality rate per 1000 ranged from 15 (Mauritius) to 260 (Angola), infant mortality rate ranged from 14 (Mauritius) to 154 (Angola) while maternal mortality rate per 100 000 ranged from 22 (Mauritius) to 1300 (DRC). In some countries, e.g. Zambia infant mortality rates that had declined significantly are on the rise once more.

Table 3. Demographic indicators for 2004 in countries within the Southern African Development Community (SADC) region.

Year	**Life expectancy at birth**	**Adult literacy**	**HDI**	**Under five CMR/1000**	**IMR/1000**	**MMR/100000**
Mauritius	72.4	84.4	0.80	15	14	22
South Africa	47.0	82.4	0.65	67	54	150
Swaziland	31.3	79.6	0.50	156	108	230
Namibia	47.2	85.0	0.63	63	47	270
Botswana	34.9	81.2	0.57	116	84	330
Lesotho	35.2	82.2	0.49	82	61	n.a.
Zimbabwe	36.6	n.a.	0.49	129	79	700
Kenya	47.5	73.6	0.49	120	79	410
DRC	43.5	67.2	0.39	205	129	1300
Madagascar	55.6	70.7	0.51	123	76	470
Zambia	37.7	68.0	0.41	182	102	730
Tanzania	45.9	69.4	0.43	126	78	580
Uganda	46.4	66.8	0.44	138	80	510
Malawi	39.8	64.1	0.39	175	110	1100
Angola	41.0	67.4	0.44	260	154	n.a
Mozambique	41.6	n.a	0.39	152	104	410

HDI = human development index: **CMR** = under five year old child mortality rate: **n.a**. = data not available: **IMR** = infant mortality rate: **MMR** = maternal mortality rate
Source: adopted from EQUINET, 2008.

In addition to poor investment in health the region faces widespread poverty which leads to poor access to clean water and appropriate sanitation and food insecurity. These factors predispose populations to diseases linked to nutritional disorders and pollution of both water and air that significantly contribute to the observed poor human well-being in the SADC region. Indications are that the Southern Africa region is double burdened by both

infectious and rising non communicable diseases. The region disease spectrum is dominated by communicable diseases caused by viruses, parasites and bacteria that may be insect-borne, water-borne or sexually transmitted. These infectious diseases include HIV/AIDS, TB, malaria, cholera. But due to environmental changes, occupational exposures, change in diet and lifestyles non-communicable diseases such as cancer, sugar diabetes, cardiovascular disease that are normally prevalent in developed countries are also on the rise as is the case with the rest of Africa.

The rate of increase in these diseases has been further exacerbated by low education, poor public health practices, increased population mobility and environmental health threats such as, inadequate infrastructure, poor waste management practices and poor governance in general, land use change as well as growing change in climatic conditions.

3.2 Climate Change in Southern Africa

3.2.1 *Observed changes*

The following observations documented by Boko et al. (2007) indicate that climate change in Southern Africa is already taking place:

• Increased episodes of warm spells and a decrease in the number of extremely cold days observed between 1961 and 2000 over different parts of the region. During this period minimum temperatures in South Africa increased slightly faster than maximum or mean temperatures.

• Although no long-term trends in rainfall have been noted in the region there was increased inter-annual variability in the post-1970 period during which higher rainfall anomalies and more intense and widespread droughts were experienced.

• Countries like Angola, Namibia, Mozambique, Malawi and Zambia experienced a significant increase in heavy rainfall events and there has been evidence of changes in seasonality and extremes.

3.2.2 *Climate change projections*

While other regions in Africa largely depend on the results of the General Circulation Models (GCMs) for projections, Southern Africa also benefits from several climate change projections based on Regional Climate Models (RCM) simulation provided by the Climate Research Group at the University of Cape Town (Christensen et al., 2007). Models largely project greater warming, a drier climate, and general increase in climate variability and extreme events particularly in the central land mass of the SADC region and towards the western areas (Desanker et al., 2001; Scholes and Biggs, 2004; Christensen et al., 2007). Details of the projections are noted as follows (Fig. 7a & b):

• The interior of semi-arid margins of central Southern Africa are some of the areas where the projected warming of the range of 0.2°C per decade (B2- low scenario) to more than 0.5°C per decade (A1- high scenario) will be greatest. (Desanker et al., 2001) (Fig. 7a).

• Modeling results show that climate change may increase the frequency of ENSO warm phases by increasing the warm pool in the tropical western Pacific or by reducing the efficiency of heat loss and this will result in more droughts in southern Africa and the opposite for East Africa (Desanker et al, 2001).

• Projected future changes in mean seasonal rainfall in Africa are less defined under intermediate warming scenarios but most models project that by 2050 the interior of

Southern Africa will experience decrease in rainfall during the growing season that exceed one standard deviation of natural variability (Desanker et al., 2001) (Fig.7b).

- Using empirical downscaling to provide projections for daily precipitation as a function of six GCM simulations, drying particularly in winter in the western portion of southern Africa was projected for the 21st century (Christensen et al., 2007).
- Under the intermediate warming scenarios a 5–15% decrease in the growing-season rainfall (November to May) by 2050 was projected (Desanker et al., 2001). Some RCMs also signaled a possibility for delayed onset of the rain season (Christensen et al., 2007).

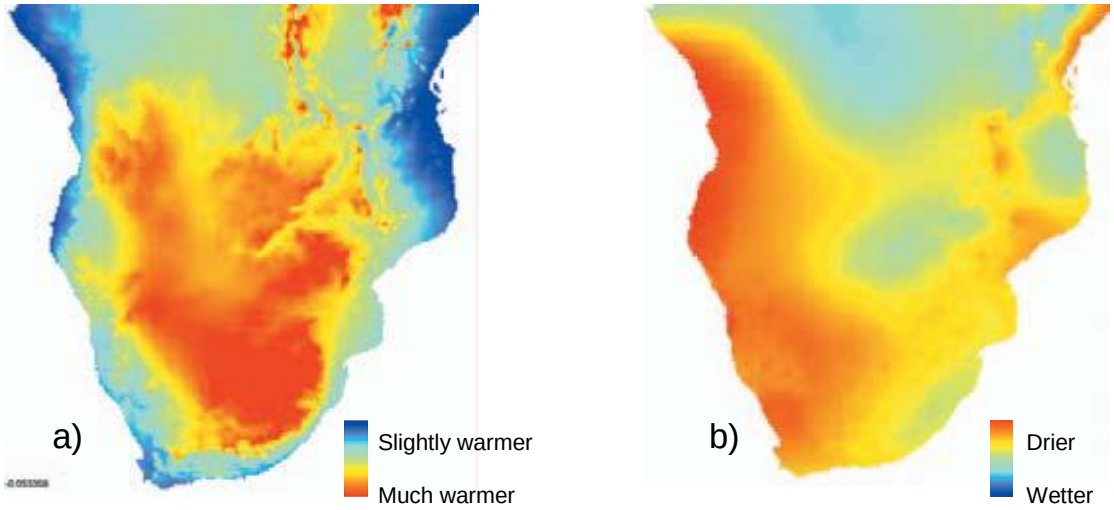

Figure 7: Projected climate change in southern Africa: HADCM3 climate model projections of changes in a) temperature and b) precipitation for 2050 relative to mean conditions over the 1961 to 1990 period, under the IPCC SRES A2 (high emissions) scenario (Scholes and Biggs, 2004).

- Both the regional modeling and downscaling results support an increase in the rainfall intensity in southern Africa. In regions of mean drying, models showed a proportionally larger decrease in the number of rain days (Christensen et al., 2007).
- The frequency of extremely dry austral winters and springs increases to roughly 20% in southern Africa while the frequency of extremely wet austral summers doubles by the end of the 21st century (Christensen et al., 2007).

- The intensity and frequency of extreme events such as drought, floods and others are likely to increase over the region. Indeed extreme events such as the 1982–1983 and the 1991/92 droughts have been credited to global warming (Alley, et al., 2007; Boko et al., 2007).
- Warming is expected to result in increases in precipitation rates and intensity of tropical storms in the Indian Ocean as with other regions but changes in frequency and spatial distribution remain uncertain. Christensen et al., (2007) concluded that there is little modeling guidance on possible changes in tropical cyclones affecting the southeast coast of Africa.

These projected changes in climate will negatively affect instrumental factors in human health such as water and food security and this is discussed in section 3.4.

3.2.3 *Vulnerability of human health to climate change*

The impacts of climate change will exacerbate poverty in a region where already nearly 40% of the people live below the poverty datum line (SADC/ESD, 2008). Malnutrition and low child weights which have implications on health are common and dietary per capita in-take of less than 2000 calories per day occur in Angola, DRC, Mozambique (up to 63% of the population face low food supplies), Namibia and Zambia. As food security in rural areas declines urban migration will increase. Estimates show that 38.7 % of the sub-region's total population live in urban areas compared to 11.2% 30 years ago (SADC/ESD, 2008). Southern Africa as with other developing countries will therefore face major challenges related to the ongoing global warming and for the immediate future, this combined with the recent Global Economic meltdown will constrain further the African region as development aid is likely to decrease. These challenges come at a time when the region's health systems are weakened by a number of factors including poor governance, inadequate resources and a serious shortage of human resources for health.

According to Robinson and Clark (2008) "Africa carries 25% of the world's disease burden yet has only 3 % of the world's health workers and 1 % of the world's economic resources to meet that challenge". Case studies for eastern and southern Africa (Chimbari et al. 2008; Dambisya et al. 2008; Dambisya, 2008; Masango et al. 2008; Munga and Mbiliny, 2008; Mwaniki and Dulo, 2008; Ndetei et al. 2008) conducted recently under the auspices of EQUINET highlight the problems that African countries face in trying to retain health professionals that are critical for normal functioning of health systems. This situation negates the efforts being made by World Health Organization (WHO) to re-emphasize and promote the principles of primary health care, in line with the Alma-Ata Declaration of 1978 (WHR, 2008).

As a result as with the case of the rest of the continent CC will be an added stress over the fragile economies of the SADC region and has the potential to reverse the little progress that has been made so far on sustainable development (Box 3 shows examples of effects of climate extremes in the economies of Malawi, Zimbabwe and Mozambique). This will reduce the limited investments ever made on health at a time when a combination of decline in water and food will be threatening further human health in the region. Thus, the anticipated added stress to health systems of Southern Africa region due to climate change is likely to result in most countries failing to attain the health related Millennium Development Goals (MDGs) number 1 (eradicate extreme poverty and hunger, number 4 (reduce child mortality), number 5 (improve maternal health) and number 6 (combat HIV and AIDS, malaria and other diseases).

Box 3. Examples of vulnerability to climate extremes in Southern Africa

Mozambique: Torrential rainfall in 2000 led to the worst flooding in 50 years, directly affecting 2 million people and with 650,000 forced to abandon their homes. The cost of the flood was estimated at US$600 million with a reduction in economic growth from a target of 10% to below 4% (Mozambique National Disaster Management Institute, in DFID, 2005).

Malawi: The 1991-92 droughts reduced real income by 8 % in Malawi. The most significant droughts in Malawi occurred in1981-1982, 1992-1993 and 2001-2002, roughly every ten years and had a negative effect on the agricultural sector, with a knock-on effect on other sectors, such as manufacturing (DFID, 2005).

Zimbabwe: The late 1991 and early 1992 severe drought in Zimbabwe had devastating impacts on the agricultural sector resulting in the reduction of real GDP by 9% and an increase in food prices by 72%. The impacts of the drought extended to other sectors of the economy, for instance on macro-economic variables there was an increase in the balance of payments deficit from 6 to 12 % of GDP over the drought period; the fiscal balance deficit increased from 7% in 1991-2 to 10% in 1992-3. The drought elevated poverty i.e. it led to a decrease in real wages by 23% in 1992, with the sharpest decline in agricultural wages by 42%; expenditure on health and education at households level and by the government declined. Other indicators of accelerated poverty were the increase in school drop-out rates; high child malnutrition and lower birth weight.

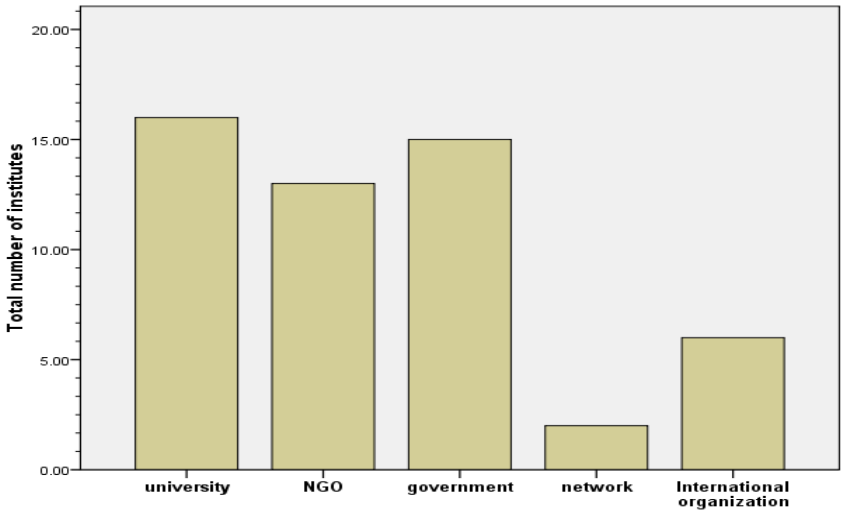

Figure 8. Number of institutions where climate change work related to health is conducted in SADC.

Figure 9 summarizes studies linking climate change to health that are ongoing or have been completed in countries within the SADC region. Most of such work is done in South Africa

and Zimbabwe, followed by Zambia and Tanzania with the rest of the countries doing very little or no such activities.

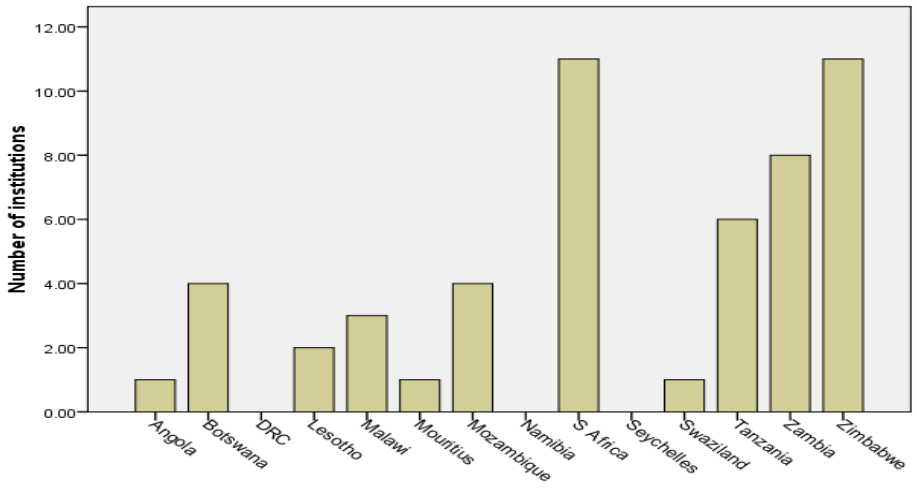

Figure 9. Number of institutions per country where climate change work related to health is carried out in SADC

An analysis of the National Adaptation Programmes of Action (NAPAs) developed by Least Developed Countries (LDCs) in the SADC region show that most of the adaptation activities are on biodiversity and agricultural activities with health activities being among the fewer activities (Figure 10). The prioritized least of the NAPAS shows in all cases that health issues are at the bottom of the priority least for countries that identified health related adaptation activities. In a priority list of 15 activities Madagascar ranked health activities as number 13 and 14, Tanzania ranked health issues as number 6 of six priorities while Zambia ranked health activities as number 9 in a priority list of 9 activities (Table 4). The Democratic Republic of Congo, Lesotho, Malawi and Mozambique do not have health activities as part of their NAPAs.

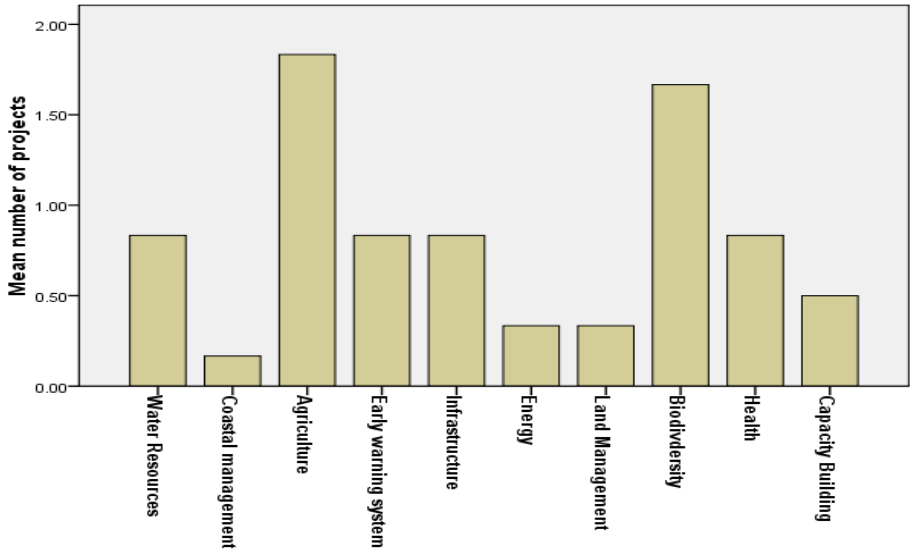

Figure 10. Projects identified by SADC Least Developed Countries (LDCs) in their National Adaptation Programmes of Action (NAPAs).

Table 4. Prioritization of health issues in National Adaptation Programmes of Action (NAPAs) developed by Least Developed Countries (LDCs)

Country	Number of projects	Health Prioritization
DRC	3	0
Lesotho	8	0
Malawi	5	0
Mozambique	4	0
Madagascar	15	13, 14
Tanzania	6	6
Zambia	9	9

3.4 Environment-Climate Change, Human Health and Scio-economic Factors

The impacts of climate on water, food security, human settlements and population movements are some of the major routes through which climate change will influence human health. Environmental factors play a major role in influencing these impacts.

3.4.1 *Water and human health*

Water resources are unevenly distributed in the region and a large section of the population lacks access to clean water resulting in heightened vulnerability to diseases. It has been projected that almost all countries in the region are likely to experience significant reduction in stream flow (Boko et al., 2007). Ground water recharge is already low and with the predicted aridity over much of the region this will decline further.

Water-related diseases have been categorised by route of transmission in terms of water-borne (ingested) and water-washed diseases (caused by lack of hygiene) (Confalonieri et al., 2007). Southern Africa is part of the African regions (excluding North Africa) that experiences loses of about 5% of GDP annually on health problems that are related to water and sanitation deficits (Economic Report on Africa, chapter 3, 2008). Water related health problems linked to water scarcity will be made worse by increased rainfall variability and high temperatures given the already poor water harvesting and management policies in the region.

Because water is closely linked to food production, these problems will further compound nutritional deficits as a result of food insecurity. Shortage of water is more likely to lead

to greater reliance on waste water recycling. Indications are that some of the organic micro-pollutants are not removed by current wastewater treatment technology more so in developing countries with limited resources and increased reliance on this source has a potential to pollute ground and surface sources and there are risks associated with use of waste water for food production which needs to be assessed (Kundzewicz et al., 2007).

3.4.2 *Food production and human health*

Kurukulasuriya and Mendelsohn, (2006) have noted that even under favorable scenarios, indications are that crop production in Southern Africa will be adversely affected by climate change. Impacts are likely to be vary with soil types and types of crops grown, for example outputs are likely to decline severely in sandy soil of the Kalahari while among crops maize will be more affected as opposed to sorghum (Ministry of Works, Transport and Communications, 2001; Chipanshi et al., 2003). A shortened growing season and lower rainfall over most of the central and western land masses of Southern Africa combined with rapid loss of moisture due to warming will marginalize further crop production in these regions and affect most subsistence farmers with already limited agricultural inputs (Dube, 2003; GECAFS, 2006). Without intervention this will directly result in increased hunger and susceptibility to disease.

Declining water supply will also negatively affect livestock production especially for subsistence farmers who rely heavily on surface water that will be rapidly lost through evapo-transpiration. CC will affect livestock production through change in the quantity and quality of livestock feed in addition to water shortages. While high temperatures and reduced water availability will directly affect the reproduction rates of cattle, for example calving rates, milk production and general body weight (Easterling et al., 2007) with implication on protein intake in the region.

3.4.3 *Climate change driven urbanisation and human health*

Frequent droughts experienced in the region since 1970s due mostly to changes in ENSO patterns have lead to a large number of people in countries such as Botswana completely abandoning crop production and moving either to cities or bigger settlements. High concentration in cities or large villages mostly unemployed and with lower education background and often with poor provision of basic services such as housing, reticulated water and sanitation and predisposes the population to rapid spread of disease especially during to climate extremes such as floods. Problems of lack of services such as sewage systems, storm water drainage systems and reticulated water are enhanced during climate extremes leading to outbreaks of infectious diseases (Economic Report on Africa, 2008).

The rate of urbanization and concentration of people in certain areas far surpasses that of provision of necessary infrastructure such as housing, serviced land, schools, hospitals and more critical jobs. Deficiency in housing and high rates of unemployment in cities is a contributory factor in diseases that spread from person to person such as TB and HIV/AIDS. The SADC/ESD (2008) summarized the urban problem in the SADC region as follows: “Rapid urbanization has led to urban sprawl and physical infrastructure deficiencies as well as depletion of natural resources and increased discharge of unprocessed wastes in the environment contributing to severe health problems in many parts of the region”.

3.4.5 *Climate change and health in coastal areas and island states*

Island states such as Reunion states, Mauritius, Seychelles and coastal areas of Mozambique all the way to Angola and DRC face even greater health risks from a combination of climate change stresses and other ongoing problems.

The Mozambique Initial National Communication Report (2003), identified Beira coast to be the most vulnerable coastal area to sea level rise with indication from modelling results that erosion and floods will be a major problem by 2075 (Annex 7). This will have major environmental and human health problems, for example, navigation channels will be affected by changes in water circulation and sediment distribution.

The increase of the temperature of the sea along the canal of Mozambique as a result of the El Niño phenomenon will have negative impacts on corals, which are an important part of the Mozambican marine ecosystem and eco-tourism. Warming of the sea will affect the resurgence processes responsible for transporting nutrients from the deep layer of oceans to the surface for feeding the fish, thus affecting the fisheries and thereby having implications on income generation, malnutrition and eventually health. An example of potential impacts of climate change on fisheries in Namibia is provided in Annex 8.

In island states, particularly in major cities or towns, hosting strategic infrastructure such as airports, seaports, industrial and central business areas and government activities tend to be located in low lying coastal areas which are most vulnerable to CC. These attractive areas are usually congested, experience land use pressure, degradation of resources, pollution of water ways and soil which will be exacerbated by CC. A combination of these factors and lack of provision of basic infrastructure such as housing, waste management will increase susceptibility to diseases. Such conditions will be economically detrimental as they reduce attractiveness to tourists and lower productivity potential leading to loss of livelihood and deepening poverty land further vulnerability to diseases.

While there is still more work required on tropical cyclones and climate change in southern Africa, current indications are that there is a possibility of increased activity in the Indian Ocean with changes in SSTs (Boko et al, 2007). Climate hazards such as tropical cyclones, storm surges and sea level rise have both short and long-term effects on human health and general livelihoods which include among others:

- Drowning, injuries, loss of property, relatives and friends leading to sudden change in family composition, which may trigger a number of psycho-social disorders resulting from, stress (Mimura et al, 2007).
- Increased susceptibility to communicable diseases due to population displacement, congestion, shortage of water. This usually increases the risk of major health problems especially for those whose immune systems have been compromised by HIV/AIDS.
- Loss of tourism attractiveness and income resulting in increased poverty
- Decline in food insecurity and malnutrition resulting from contaminated coastal land that makes soil unsuitable for cultivation due to sea level rise (Government of Seychelles, 2000) and also disturbance food distribution infrastructure. Current projections show greater likelihood of sea level rise leading to loss of productive land to flooding and salinisation.

- Increased geographical range of diseases where inundation and flooding extend into areas that hitherto were not affected extending some of the infectious disease range into population that has no immunity.

Southern Africa may also face rapid migration to coastal zones where inland areas become less productive due to, for example, persistent drought.

It can therefore be concluded that Southern Africa will face a complex convergence of challenges; ranging from consequences of unsustainable use of natural resources, globalisation and unequal terms of trade, to effects of climate change which together will lead to rapid loss of quality and quantity of water supply, biodiversity and food production leading to greater susceptibility to climate risks such as flooding and droughts, reduced food security, decline in human wellbeing and increased susceptibility to infectious and non-communicable diseases. Climate extremes such as floods, extreme temperatures, droughts and heat waves will be a great strain to management of health risks and to the resilience of health service delivery infrastructure.

This section has used water, food resources, urbanisation and coastal regions to demonstrate the wide ranging inter-linkages between environment and human health.

3.5 Climate Change and Infectious Diseases in Southern Africa

3.5.1 *Studies on climate sensitive communicable diseases*

As in other parts of the world climate change in Southern Africa will change environmental conditions that influence the geographical extent and transmission of climate sensitive infectious diseases. Temperature, humidity, rainfall, soil moisture and rising sea level are particularly important environmental factors although these will interact with a number of demographic and socio-economic factors. The results of Medline search for published articles on malaria, schistosomiasis, cholera, diarrhoeal diseases and meningitis in which climate was mentioned are presented in Figure 11. The highest number of studies was for malaria followed by schistosomiasis with the least number of studies being for cholera. Table 5 indicates for

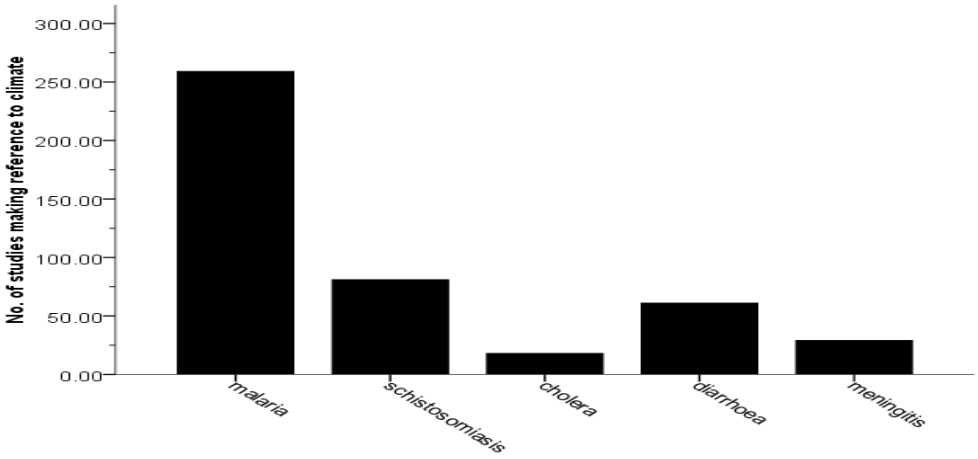

Figure 11. Number of studies conducted in SADC countries on various diseases making reference to climate

malaria and schistosomiasis the total number of studies and those in which climate is mentioned. A total of 925 707 studies on malaria compared to a total of 1 162 studies on schistosomiasis were identified. Out of the total number of studies identified only 2 293 malaria studies and 81 schistosomiasis studies made reference to climate, suggesting that

Table 5. Total number of malaria and schistosomiasis studies and; studies for the same diseases put in context of climate change for SADC countries identified by Medline search

Country	Total No. of malaria studies	Malaria and climate change studies	Total No. of schistosomiasis studies	Schistsosomiasis and climate change studies
Angola	60	2	29	0
Botswana	25	5	10	1
DRC	11	0	1	0
Lesotho	4	0	1	0
Malawi	345	1	66	19
Madagascar	284	44	103	6
Mauritius	27	0	16	0
Namibia	21	1	3	0
Seychelles	5	0	0	0
South Africa	1 498	116	329	24
Swaziland	24	3	5	0
Tanzania	923	55	245	11
Zambia	207	10	109	6
Zimbabwe	196	22	245	14
*Total	925 707	2293	1162	81

*Total includes studies that mentioned climate change and studies that did not mention climate change.

Proportionally much less studies have been conducted in the context of climate change. Across countries much more malaria studies making reference to climate were conducted in South Africa, Tanzania, Madagascar and Zimbabwe than in other SADC countries. Similarly the same countries with the addition of Zambia were observed to have many studies on schistosomiasis that made reference to climate. These analyses do not categorically suggest that studies making reference to climate were indeed climate change related studies but illustrate that climate variables were considered in the studies.

The studies on the above mentioned diseases in which climate is referred to are presented by country in Table 6 Most of the studies on malaria were conducted in South Africa followed by Tanzania and Madagascar. For schistosomiasis the highest number of studies was conducted in South Africa followed by Malawi. For cholera, diarrhoeal diseases and meningitis were South Africa has the highest number with less than three or no studies for the rest of the SADC countries except for Zimbabwe where 7 studies were identified for diarrhoeal diseases.

3.5.1.1 *Schistosomiasis and climate changes*

As noted above there are limited studies in the SADC region that have specifically focused on climate change with respect to schistosomiasis.

Van der Werf et al (2003) reviewed the relationship between the presence of schistosome infection and clinical morbidity with the aim of estimating the numbers of individuals with disease-specific morbidity for *Schistosoma haematobium* and *Schistosoma mansoni* infection in sub-Saharan Africa. The

Table 6: Number of studies for various diseases making reference to climate for each country

Country	Malaria	Schistosomiasis	Cholera	Diarrhoea	Meningitis
Angola	2	0	1	0	1
Botswana	5	1	0	0	0
DRC	0	0	0	0	0
Lesotho	0	0	0	1	0
Malawi	1	19	2	2	1
Madagascar	44	6	3	3	0
Mauritius	0	0	0	0	0
Namibia	1	0	0	0	1
Seychelles	0	0	0	0	1
South Africa	116	24	9	44	20
Swaziland	3	0	0	0	0
Tanzania	55	11	2	3	2
Zambia	10	6	0	1	2
Zimbabwe	22	14	1	7	1

study concluded that results of morbidity and mortality due to schistosomiasis indicated that schistosomiasis was an important public health problem in sub-Saharan Africa. The prevalence of haematuria for some countries in the SADC region was reported as follows; 16% for Zimbabwe, 18% for Angola and Tanzania; 20% Malawi and 24% in Mozambique.

Moodley et al. (2003) used Geographical Information Systems (GIS) to produce temperature-suitability maps for schistosomiasis in South Africa where urinary and intestinal schistosomiasis occurs widely. But due partly to limitations of the available disease data it was not possible to predict the prevalence of schistosomiasis in the identified climate-suitable areas. Tanzania Partnership for Child Development in Dar es Salaam and Mwanza Research Centre in Mwanza collaborating with scientists from UK and USA to use remotely sensed satellite data and logistic regression to develop prediction maps of the probability of having infection prevalence exceeding 50% which according to WHO guidelines would warrant mass treatment. The model performed reasonably well in coastal areas where it identified an ecological zone with the intermediate-host snail species responsible for transmission.

A similar attempt was made by Simoonga et al. (2008) who used GIS to study the spatial heterogeneity distribution of urinary schistosomiasis in Zambia. The study combined information on variables like temperature, rainfall with the satellite based normalized difference vegetation index (NDVI) data.

In another study it was shown that communities in South Africa used herbal remedies to treat urinary schistosomiasis. Sparg et al. (2000) at the School of Botany and Zoology at the University of Natal in South Africa screened twenty-one plant species for their antischistosomal properties and found that plant extracts from *Berkheya speciosa* (Asteraceae), *Euclea natalensis* (Ebenaceae) and *Trichilia emetica* (Meliaceae) were lethal to the schistosomula. This study shows the significance of establishing the scientific basis of indigenous knowledge systems on health issues and but also how negative effects of climate change on environmental resources, in this case biodiversity will impact on human health. For example, prolonged drought or overly wet periods may lead to loss or change in vegetation cover and species composition thus undermining the use of this knowledge to improve human health in the region.

Appleton (2008) made a review of the distribution of intermediate host snails for schistosomiasis in the Okavango Delta and concluded that schistosomiasis in Maun village would be determined by hydrological cycles in the Okavango Delta that in turn are dependent on rainfall occurring in upper Okavango basin. Chimbari (2009) (personal communication) is currently conducting a study to validate the predictions made by Appleton (2008).

3.5.1.2 *Malaria and climate change*

One of the biggest environmental health threats in Southern Africa that is climate sensitive and closely associated with water is malaria. Malaria epidemics in Zimbabwe have been found to be closely linked to climatic variability caused by events like El Niño (WHO, 2003). Hartmen et al. (2002) also assessed climate suitability for stable malaria transmission in Zimbabwe under different scenarios and

produced the map shown in Figure 12 which shows a much wider distribution of malaria transmission zones. These predictions are consistent with observations made by Chirebvu et. al. (1999) who noted unusually high numbers of malaria cases in the eastern highlands of Zimbabwe where temperature has been a limiting factor for malaria transmission in the past.

Craig et al. (2004) from the Medical Research Council in Durban, South Africa used 30 years of confirmed malaria case data from KwaZulu-Natal to examine short- and long-term trends in relation to climatic and socio-economic factors. They found that about 50% of the total variation in seasonal changes in case numbers were explained by climatic variables such as mean maximum daily temperatures and total rainfall during the current summer months. The study however, concluded that overall levels were associated with non-climatic factors such as drug resistance and HIV/AIDS infection. These observations concur with those made earlier by Small et al., (2003) who noted that investigations on recent resurgence of malaria across Africa should focus on models of precipitation patterns and on closer examination of the role of non-climatic influences, such as the rise in drug resistance.

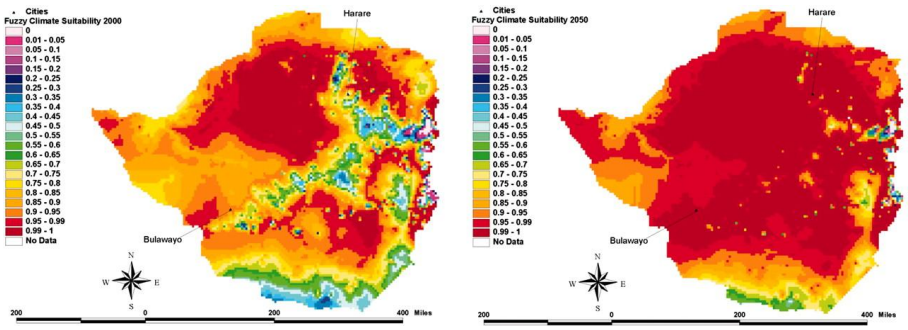

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Figure 12. Climate suitability for stable malaria transmission across the diverse topography of Zimbabwe, determined by fussy logic analysis and based on United Kingdom Meteorological Office (UKMO) global climate scenarios for year 2000 (Left) and with warming to the year 2050 (Right)

Small et al., (2003) in the Department of Geography at the University of Maryland used a climate-driven biological model of malaria transmission for the entire African

continent for the period between 1911 and 1995 and found that southern Mozambique was the only region for which climatic suitability conditions for malaria consistently increased. This suitability was linked to increases in precipitation rather than temperature. This work also found that areas where climate was becoming less suitable for transmission had experienced decreased rainfall over the study period while areas such as south-western Congo basin and north-western Tanzania which had been subjected to fluctuations in rainfall rather than temperature experienced highly variable, episodic climate suitability for malaria transmission.

Work by Korenromp et al., (2004) noted that the proportion of children deaths due to malaria in East and southern Africa rose from 18% to 37% between 1982–89 and 1990–98. The high death rates associated with malaria were linked to complex interactions involving climatic conditions, land use systems that create favourable conditions for mosquitoes to breed, lack of capacity to establish and maintain a malaria early warning system, and limited access to medical facilities and other preventive measures such as insecticide-treated bed nets, all of which relate to poverty, low public education and development. For this reason indications that climate change may result in the spread of malaria beyond its normal zone thereby affecting populations that have compromised immunity and who live under extreme poverty, is of great concern.

Thomson et al (2005) showed strong link between periods of unusually high or low malaria anomalies in Botswana using both sea-surface temperature and multi-model ensemble seasonal climate forecasts that are able to provide routine seasonal forecasts for malaria control in southern Africa. Analysis of retrospective malaria data in Maun, Botswana showed that transmission of malaria was correlated to hydrological cycles that determined the flow of water in the Thamalakane River.

The following future projections of Malaria have been suggested for Southern Africa:

- By 2050 and continuing into 2080, some parts of southern-central Africa could become unsuitable for malaria transmission (Boko et al., 2007; Thomas et al., 2004).).
- Other work based on 16 climate change scenarios show that by 2100, changes in temperature and precipitation could alter the geographic distribution of malaria in Zimbabwe with previously unsuitable areas, (high land in particular) of dense human population becoming suitable for transmission (Hartmann et al., 2002).
- By 2080s areas currently with low values for stable transmission in the central Angolan highlands could also become highly suitable. In fact all scenarios point to highlands areas of southern Africa becoming more suitable for transmission (Hartmann et al., 2002; Ebi et al., 2005).
- Strong southward expansion of the transmission zone will likely continue into South Africa by 2100 as water linked hazards such as floods trigger malaria epidemics in arid and semi-arid areas (Boko et al., 2007; Hartmann et al., 2002).

3.5.1.3 *Climate change and diarrhoeal and cholera related epidemics*

Cryptosporidium parvum which has been found to be associated with up to nearly 30% of all incident diarrhoeal illnesses in children in tropical countries was investigated over one

rainy season in crowded townships of Lusaka, Zambia (Nchito et al.1998). The study found that 18% of children with diarrhoea were infected and this was linked to higher levels of oocyst contamination of drinking water during the rainy season. However, other confounding factors such as high HIV seroprevalence in the community under study were considered influential since cryptosporidiosis was common among HIV- seropositive (14%) individuals than among HIV-seronegative (8%) children with diarrhoea. Such findings demonstrate the future likely complications in human health resulting from the interactions between climate change related stress and existing stresses from other sources.

WHO, (2003) have noted that the rise in sea-surface temperature and excessive flooding during the 1997/98 El Niño provided conducive conditions for cholera epidemics in countries along the Indian Ocean e.g. Mozambique and Tanzania. Warming in the Great Rift Valley lakes may also cause conditions that increase the risk of cholera transmission (Birmingham et al., 1997).

3.5.1.4 *Meningococcal meningitis and climate change*

The outbreak of meningococcal meningitis (MCM), an infection of the meninges, caused by the bacteria *Neisseria meningitides,* results from an interaction between different environmental parameters such as immune receptivity of individuals, poor socioeconomic conditions, social interactions such as pilgrimages, migrations; and some specific climatic conditions. Transmission of meningitis in Africa has been limited to semi-arid areas including Southern African countries such as Botswana particularly during periods of dryness, very low humidity, and dusty conditions (Desanker et al., 2001). From what is known as the "Meningitis Belt", it has been established that the outbreak usually starts at the beginning of February and disappears in late May. Currently most of the countries affected in Southern Africa fall mainly with the medium risk zone but it is not known how this might change due to climate change in future (Boko et al., 2007).

3.5.1.5 *Tsetsefly - vectors of trypanosomes and climate change*

There is limited work within the SADC region on the implications of climate change on tsetse fly. Collaborative work by Roninson et al. (2008) involving scholars form the UK and the Epidemiology Research Unit in Johannesburg, South Africa used satellite data, in particular, the normalised difference vegetation index (NDVI) to map environmental characteristics of areas of tsetse (vectors of trypanosomes) presence and absence. They found that this method can be used to characterize differences between tsetse species and subspecies e.g. *Glossina morsitans centralis*, *Glossina morsitans morsitans* and *Glossina pallidipes* in southern Africa. The results point to the possibility of using satellite data for making predictions about the distribution of tsetse fly and providing early warning information under climate change.

3.5.2 HIV/AIDS and climate change

In addition to health risks that are directly linked to climate, Southern Africa is facing huge long-term health problems and loss of productivity due to the HIV/AIDs pandemic. Countries such as Botswana, Zambia, Malawi and Lesotho, have been affected to the extent that life expectancy has been reduced from 62 years in 1990-1995 to 39-48 years in 2000-2005 (CHGA, 2008; UNDP, 2005). HIV/AIDS affects the most productive age group (15-49 years old) resulting in far reaching negative impacts on the economic productivity of the region. Projections point to a grave future in the food production due

to losses linked to HIV/AIDS. Loses in agricultural labour in some of the most affected countries such as Namibia, Mozambique, Botswana, South Africa and Zimbabwe could be 20% or more (Figure 13) and this serves to enhance climate related stresses. HIV/AIDs disproportionately impacts on women, increasing their vulnerability to climate related health problems but also on the population as a whole given the central role of women in reproduction, caring, nurturing and in economic development of the region.

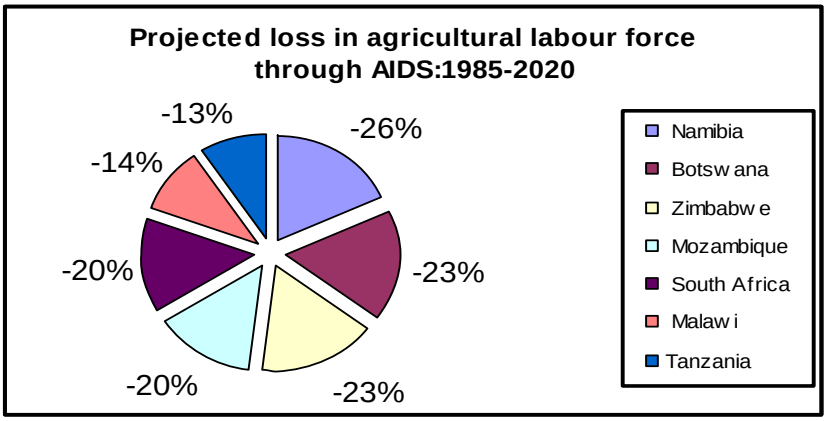

Figure 13. Projected Loss in Agricultural Labour Force due to HIV/AIDS, 1985-2020, among some of the most affected countries in the SADC region (Source: UNDP, 2005)

The spread of HIV/AIDs is linked to complex socio-economic factors including lack of economic opportunity resulting in migration and disruption of family structure. Increased frequency and intensity of drought under climate change will result in loss of key ecosystem services for livelihood and accelerate environmental refuges, sharpen inequalities in access to dwindling resources and increase the rate of urbanisation. Often people migrate to cities with the hope to find employment yet most end up un-employed, with no proper housing, and food leading to survival strategies that make them vulnerable to contracting HIV and or rapidly progressing to full blown AIDS due to poor nutrition and living conditions. Reduced immunity increases susceptibility to climate driven diseases such as malaria, diarrhoeal diseases and other opportunistic diseases that are also linked to living under poor and congested areas such as TB. Climate change will be a major driver of factors that trigger population movement and that reduce the productive capacity at household level leading to poverty and increased risk of HIV/AIDS. Factors that cause malnutrition, poverty, inequalities in access to resources also drive the HIV/AIDS pandemeic in Africa (Anantram, 2006).

The interaction between HIV/AIDS and climate change that has been discussed here indicates further the complex inter-linkages between environmental factors and human health.

4.0 SYNTHESIS

4.1 Climate Change in Southern Africa

Climate observations show that the SADC region is warming up. There has been an increasing trend in the number of warm spells and a decrease in the extremely cold days. Rainfall trends are variable but evidence point to an increased inter-annual variability, extremely wet periods and more intense droughts in different countries. Future projections show that changes will not be uniform over the region. The central southern land mass extending over Botswana, parts of north western South Africa, Namibia and Zimbabwe are likely to experience the greatest warming; 0.2°C to 0.5°C per decade. Most of this area is also likely to experience more intense droughts linked to changes in ENSO patterns. The SADC region may experience delayed onset of rainfall and reduced growing season rainfall with periods of more intense rainfall events leading to floods. Warming may also increase the intensity of tropical storms in the Indian Ocean.

4.2 Status of Human Health in Southern Africa

Review of literature on the global status of human health showed that in the last 30 years there has been a significant improvement indicated by reduced child mortality rates, infant mortality rates and maternal mortality rates. It is, however, clear that the level of improvement in Europe and North America has been much higher than in other regions with Africa lagging behind all the continents. The reasons why Africa has not done so well in improving the population health include poverty, poor education, poor governance, conflicts, and weak health systems, environmental factors including climatic conditions that promote transmission of major killer diseases and reduced agricultural productivity. Furthermore drug resistance, HIV/AIDS, re-emerging diseases and increases in conditions like cardiovascular diseases and obesity that used not to be of major concern to Africa have diluted the gains made towards improving population health and in some cases reversed them.

Major inequities in health were observed at global level and within the African region. The inequities were associated with the economic performance of the countries. Within SADC there are 7 Least Developed Countries (LDCs) whose health indicators show a worse situation than in other middle income countries within the same region. This implies that the ability to mitigate and the adaptive capacities to deal with the effects of environmental factors such as climate change are worse in poorer countries than middle income countries. Overall, all countries in the SADC region are experiencing serious brain drain in the health field, thus weakening the health systems and hence reducing the capacity to deal with challenges posed by climate variability and climate change. The current global meltdown is likely to impact negatively on the health status of developing countries, particularly in southern Africa since the level of development aid is likely to decline.

4.3 Mapping of Studies on Climate Change and Health

The inventory of work on climate change showed that climate change has become very topical with many recent conferences and workshops carrying climate change themes. At global level, work linking climate change and health has been tremendous judging from the recent EcoHealth Conference held in Merida, Mexico in December 2008 where over hundred papers addressing climate change and health were presented. In Africa, not much work linking climate change and health has taken place. Although only institutions working on climate change in southern Africa are presented in this report, there is evidence that much more work on climate change and health has been done in east Africa than in southern Africa.

The mapping of institutions working on climate change showed that there are very few institutions that specialize in climate change and health. Most institutions work on cross cutting issues of climate change with the majority of them focusing on adaptation. This bias towards adaptation arose from evidence of the IPCC reports that suggested that climate change will definitely occur even if gas emissions were significantly reduced at this stage. It is therefore logical to prepare populations for the inevitable adverse conditions. Evidence on impacts of climate variability and climate change seems to be more apparent in the agricultural and water sectors; and therefore most institutions find this area of study more attractive. A close look at the National Adaptation Programmes of Action (NAPAs) for LDCs prepared with support from UNFCCC; clearly show that health has not been prioritized. Out of the 7 LDCs in SADC only Madagascar, Zambia and Tanzania presented projects on health while the remaining 4 namely DRC, Lesotho, Malawi and Mozambique did not field any projects on health.

It is evident from the mapping done that much of the work on climate change is done through networks. In fact there are more networks than institutions that are conducting work on climate change. A total of 36 networks were identified and it must be noted that the list is not exhaustive. Almost all meetings held by networks in the past 5 years resolved that there is need to carry out institutional mapping but surprisingly this work has not been done except in the case of South Africa which has a huge database of institutions working on climate change. Some of the networks and institutions that have indicated an interest to carry out mapping exercises include African Technology Policy System (ATPS), Capacity Strengthening of Least Developed Countries on Climate Change Adaptation (CLACC), ZERO Zimbabwe, CARE Zimbabwe, Global Network on Climate Change in Africa (in the process of being formed), African Climate Change Fellowship Programme (ACCFP) Climate Change Adaptation in Africa (CCAA) and the current initiative involving Danish networked institutions and southern institutions.

Despite the considerable large number of institutions and networks working on climate change, there is limited published work on climate change and human health in the SADC region. This probably indicates the difficulty in sourcing research funds to support laboratories that carry out the work. The few studies conducted in the region have mainly been through some collaboration between scientists in the region and their northern counter-parts. Some of the studies in Tanzania and South Africa attempted to use GIS and remote sensing to determine the geographical patterns of potential disease risk areas for early warning purposes. As with the rest of Africa malaria has received more attention while other potentially climate sensitive diseases received less attention.

4.4 Linkages Between Climate Change and Socio-economic Factors

An analysis of potential impacts of climate change on water and food production shows that climate change impacts will result in complex interactions that will compromise human health. Southern Africa is a region already facing numerous environmental threats to health such as water shortages which will be exacerbated by climate change. Apart from increased health hazards during climate extremes, reduced food security will increase malnutrition and increase vulnerability to numerous diseases. Loss of productivity of land will drive people to cities where already low provision of sanitation facilities is compromising people's health. Coastal areas could face complex health problems linked to sea level rise resulting in reduced

fresh water supply and agricultural land. In addition rising sea surface temperature may increase conditions for cholera outbreaks. Added to these factors is how climate change induced poor human wellbeing will interact with complications linked to the spread of HIV/AIDS in the region. All these inferences made from combined pieces of evidence need to be validated through an integrated and sustained climate change and human heath regional research programme.

5.0 CONCLUSIONS

Assessment of the status of health in SSA showed that the region is overburdened by poor environmental health leading to high susceptibility to various diseases, stagnant or declining economic growth and health systems that are gradually being weakened. It is evident that SSA is overly vulnerable to impacts of climate change mainly in the agricultural and water sectors that have serious bearing on population health status. While there is growing evidence, globally, on climate change and human health with particular reference to climate sensitive diseases like diarrhoeal diseases, dengue, malaria, schistosomiasis, trypanosomiasis and under-nutrition and others, limited work has been conducted or is ongoing in Southern Africa.

Much of the inferences made regarding impacts of climate change in Africa, particularly with regard to health, are based on scanty data. This is more so in the case for the SADC region where there is limited past and ongoing work on climate change and human health in general. The resurgence of malaria has been linked more strongly to socio-economic issues including drug-resistance than to climate change.

Indirect effects of climate change on diseases through the responses of socio-economic conditions to changes in climate leading to increasingly favourable conditions for the spread of these diseases are not emphasized in most studies. Such responses include increased migration to cities leading to congestion and shortages of critical facilities that may increase the spread of for instance flood induced diseases such as cholera and diarrhoea or exposure of more people to HIV/AIDS infection, thus making them more vulnerable to climate driven diseases. A more integrated approach to human health and climate related diseases is therefore required.

Assessing climate sensitive diseases for national policy needs is greatly constrained by the difficulty of reliably attributing observed temperature changes to diseases outcomes particularly at smaller scales where natural climate variability is relatively larger. Nonetheless, some studies like one in Botswana have demonstrated the link between malaria outbreak and seasonal climatic factors and made it possible to develop early warning preventive measures.

Many climate change networks are operating within southern Africa but they seem to be working in isolation and information on their activities is not readily available.

6.0 RESEARCH GAPS AND RECOMMENDATIONS

The limited studies addressing climate change and human health that have been conducted in the region have mainly been through some collaboration between SADC scientists and their northern partners. Such collaborations need to be facilitated to build local capacity. However, without deliberately providing resources for research in human health and climate change the human capacity produced may not be effectively used in the region. Sustainable mechanisms for providing resources to build laboratories and provide the needed supplies to conduct such research is required and this could be achieved through cooperation between national Governments and international development Agencies.

Understanding climate change and human health requires locally relevant knowledge on climate change. Currently available information is of broad scale thus making it difficult to use for policy formulation. More resources are needed to provide climate change information at a local scale. For example, the region could benefit from capacity for modelling possible changes in tropical cyclones affecting the southeast coast of Africa to determine the implication on health. There is also need for further research on how patterns of ENSO may change with increasing warming and the implications of this on future climate variability in Southern Africa

Although relatively better understanding of malaria exists, more work needs to be done particularly monitoring the infection in terms of both climatic and socio-economic factors as well as population mobility.

Focused research on climate change and socio-economic factors affecting the transmission and control of schistosomiasis, intestinal helminths and meningococcal meningitis diseases is required. Also essential is monitoring and developing early warning systems for these diseases as well as others such as cholera and diarrhoeal infections.

Treated effluent water for irrigation and other non-domestic uses is increasingly becoming necessary in view of the anticipated decrease in rainfall in southern Africa. Thus, the importance of understanding the implications of using such water to human health cannot be underscored.

Exposure to extreme events such as severe drought or flooding leading to loss of production capacity, family and displacement results in psycho-social disorders that are rarely documented. Information on mental stresses resulting form disasters will provide valuable information required in the post disaster rehabilitation period.

There is need to establish networks to motivate, rally policy makers and share knowledge over these pertinent but neglected issues and provide linkages to scientists abroad. Establishing and running such networks requires resources and therefore support of international organisations and developed countries is much needed in the initial stages.

7.0 WAY FORWARD

This study has shown that no network or institution is specifically addressing linkages between climate change and health in the SADC region. It is therefore important that such a network is established. The proposed network should also address environmental health in general with special emphasis on linkages between climate change, water and food security which are important determinants of human health. Given that there are already many networks within the region efforts should be made to collaborate with those networks in order to avoid duplication of activities.

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9. ANNEXES

9.1 Annex 1: Terms of Reference

Overview of Research Projects on Climate Change, Human Health, Water and Food Security in Southern Africa

Background

The Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) of 2007 highlights Africa south of Sahara as one of the most vulnerable regions in the world with regard to climate change. The report further states that there is evidence that some areas in Africa, including parts of southern Africa, are highly vulnerable to climate variability and change.

Current climate predictions for southern Africa foresee increased variability and changes of different climate factors. These changes are expected to impact on human health, water and food security through modifications of environmental and socio-economic determinants.

The agricultural sector is crucial in terms of sustaining local livelihoods and contributing to the GDP in all SADC (Southern African Development Community) countries. Recent assessment studies, including regional-scale analysis, estimate significant decrease in suitable rain-fed land for crop production. Some parts of the southern Africa are likely to experience considerable reductions in maize production with serious implications for food security and human nutrition, especially among poor and vulnerable groups. Food insecurity and malnutrition is also likely to be further aggravated by climate change interacting with other multiple stressors such as HIV/AIDs, poor governance and poor adaptation. Water, primarily in the form of rainfall, is one of the most important resources in all SADC countries. Changes in temperatures and rainfall patterns associated with global warming will therefore have significant consequences for a wide range of environmental and economic activities. Climate variability and climate changes are also expected to lead to changes in disease distribution, range, prevalence, incidence and seasonality. Such changes may in turn cause health risks from flooding, changes in temperatures and precipitation. Southward expansion of the transmission zone of malaria may likely occur. It is worth noting, however, that not all changes in climate will be negative, and that the impact of climate change on e.g. water resources, is not uniform. Positive changes may also occur in some parts of the region under favourable scenarios with lengthened growing season and rainfall changes.

Against this background it is clear that adaptation to climate change is closely linked to issues of sustainable development. Climate change and variability is an additional hindrance and a serious threat to achieving the MGD's in Africa. Given its low income, weak institutions, limited knowledge, responding to the impacts of climate change will be a huge challenge for southern Africa.

Detailed and context specific knowledge of the consequences of climate change at global, regional, national and local levels is vital for overcoming the negative effects of climate change in southern Africa, and to secure the most needed and efficient adaptation to climate change. In order to facilitate the access of policy-makers and development practitioners to the results from existing research on climate change in SADC and enhance networking and knowledge sharing for action, the three Danish research networks: Danish Development Research Network (DDRN), Danish Water Forum (DWF), and the Danish

Research Network for International Health (SUNNET) have decided to develop three separate overviews of research projects and key institutions and networks working within the area of climate change and climate variability focusing on mapping:

i. Research projects on **climate change and human health** (overview 1)
ii. Research projects on **climate change and water** (overview 2), and
iii. Research projects on **climate change and food security** (overview 3)

The mapping of research projects and key institutions will be at the regional-scale focussing on southern Africa represented by the SADC countries. The focus will be on recent research since 2003, but earlier highly relevant work may be included. Both atmospheric sciences, including biophysical science and sociological and economic sciences will be covered.

The mapping/overviews will be presented at a planned North-South-South regional knowledge sharing workshop on "Climate Change, impacts on food security, health and water" to be held in South Africa in February 2009. Furthermore, it will facilitate the development of joint research proposals, and inform developing practices and policies within the areas covered by the networks.

Objectives of the three consultancies

Based on a desk study of relevant projects and documents the main purpose of the consultancies is to provide

a. A profile of key research institutions in the SADC region with competences and activities within climate change and human health (overview 1); climate change and water (overview 2), or climate change and food security (overview 3).
b. An overview of the results from ongoing and recently completed collaboration research projects on on climate change and and human health (overview 1); climate change and water (overview 2), or climate change and food security (overview 3) in the SADC region.

Outputs
Each of the consultants will be responsible for compiling a report including:

- An overview of existing knowledge and outcome of research projects regarding climate change and one of the three focal themes (human health, climate change and water, and climate change and food security) in the SADC region. The overview will cover research since 2003 (but earlier highly relevant work may be included) and include current research projects and publications by leading research institutions in the SADC region undertaken by individual researchers, research groups, institutes and universities.
- Identification of linkages between the focal themes (health, water or food security) and interaction with other factors
- A mapping of the institutions that operate within the region linked to climate change and the relevant focal theme (health, water or food security). The mapping should serve as a useful tool in identifying partners and supporting the development of future joint research projects.
- Identification of research and knowledge areas of common interest to researchers and development practitioners
- Recommendations on 'gaps' and perspectives on future research collaboration areas

9.2. Annex 2: Some of the factors that predispose Africa to climate change stress (Desanker et al., 2001; Boko et al., 2007; Scholes et al., 2008).

Areas of Vulnerability	Description
Low development status	Per capita gross domestic product (GDP), life expectancy, infant mortality, and adult literacy are all in the bottom quartile globally when averaged across Africa
High External Trade and Aid Dependence	Most African countries have limited access to capital and to markets, are chronically dependent on financial aid and face heavy international debts servicing burdens. The rate of economic diversification is low and there are limited inter-regional trade linkages to buffer economies from changes in global trade.
Widespread poverty	Africa was the only continent with a declining trend in income per capita over the 1980-2000 period. Most countries suffer widespread un-employment, inequitable access to resources and gross gender disparities. Majority of the population is directly dependent on climate sensitive sectors such as agriculture and eco-tourism.
Disease Burden	Africa is facing disease burdens that are linked to lack of safe water, poor personal and domestic hygiene and inadequate sanitation practices. Numerous lives are lost due to malaria, cholera, tuberculosis. Out of the estimated 700, 000 to 2.7 million people who die of malaria each year, 75% are African children and the economic burden of malaria is estimated at an average annual reduction in economic growth of 1.3% for those African countries that are most affected (Boko et al., 2007). The health and indeed the whole development process in Africa is currently threatened by the HIV/AIDS pandemic.
Hunger	Indications showed that by 2004 40% of the sub-Saharan population was undernourished (Desanker et al., 2001). A number of countries are under perpetual food deficit and even mild or one year long droughts result in a food crisis.
Literacy and human resource	By 2004 over 60% of the adult population was estimated to be illiterate (Scholes et al., 2008). The productivity of the labour force is generally inefficient and Skilled human resources are lacking.
Poor governance	A major constrain in development of the continent is weak governing institutions and armed conflicts resulting in displaced people, some of the factors leading to accelerating ecosystems degradation and increased susceptibility to environmental hazards such as drought and floods.

9.3 Annex 3: Likely impacts of climate change on human health in Africa.

Health risks in Sub-Sahara are linked to low development, poverty and hunger and are currently confounded by HIV/AIDs pandemic which increases further vulnerability of health of the population to future climate change induced health problems (UNDP, 2005; Thornton, 2006):

- Climate change will lead to further decline in food production, difficulties in accessing food through imports and loss of natural products resulting in high incidents of nutritional deficiency affecting most those whose immunity is compromised e.g. HIV/AIDs
- There is a strong link globally between high temperatures and common forms of food poisoning e.g. salmonellosis and these needs to be investigated for the case of Africa. Pests such as flies, rodents, and cockroaches increase under warmer temperatures and this increases the probability of contact with food which may threaten human health (Confalonieri et al., 2007).
- Drought leading to accelerated land degradation and dust storms may affect air quality and exacerbate respiratory health problems such as asthma and tuberculosis (Thornton, 2006).
- Water shortages e.g. during drought will exacerbate the potential of outbreaks of water-borne diseases such as cholera (e.g. through unhygienic practices), intestinal worms and typhoid. While periods of very high rainfall may lead to floods and outbreak of waterborne diseases e.g. cholera through contamination of piped and other fresh water sources (Desanker et al., 2001 Confalonieri et al., 2007; Kundzewicz et al., 2007).
- Exceptionally wet periods combined with high relative humidity may provide optimum conditions for the spread of insects and pests resulting in diseases such as malaria spreading beyond their normal zones into population that have low immunity to such diseases (Desanker et al., 2001; Dube, 2003). Long periods of below average rainfall will increase the population of non-immune malaria people hence increasing susceptibility to infection during wet periods (Confalonieri et al., 2007).
- Temperature extremes for e.g. unusually hot or cold weather as well as very wet periods will also be a health hazard and the effect will depend among others on the type of housing infrastructure, education and income levels, general health status and age group. The elderly are more vulnerable to heat wave and injuries from storms, and floods.
- Climate change may increase the spread of other diseases for example drought, low humidity and dust storms may provide conditions for meningococcal (epidemic) meningitis (Confalonieri et al., 2007).
- These climate related health problems will affect most those whose immunity is already compromised for example HIV/AIDS infected groups or displaced populations (Thornton, 2006; Confalonieri et al., 2007).

9.4. Annex 4: Land use and agricultural potential of the SADC countries in 1987 ('000 ha) (Stilwell, 2000)

Country	Land Area	Potential Agr. Area	Cultivated Area	Forestry & Others	Irrigation Area	Cultivated Agr. Area (%)	Cultivated area Irrigated (%)
Angola	124,670	31,500	3,500	93,500	10.0	11.1	0.3
Botswana	58,537	5,330	1,330	53,207	2.0	25.0	0.2
Lesotho	3,035	861	361	2,174	1.0	42.0	0.3
Malawi	9,408	3,273	2,273	6,148	18.0	69.0	1.0
Mozambique	78,409	40,409	3,080	38,000	70.0	7.6	2.3
Namibia	82,329	-	662	43,667	4.0	-	0.6
South Africa	122,320	29,057	13,174	4,369	1,130.0	45.3	8.6
Swaziland	1,720	364	161	1,364	62.0	44.2	3.5
Tanzania	88,604	45,030	5,030	43,574	146.0	11.2	2.9
Zambia	74,071	24,998	4,998	49,074	20.0	20.0	0.4
Zimbabwe	38,667	3,524	2,524	35,143	185.0	71.6	7.3
Total	**681,770**	**184,346**	**37,093**	**370,220**	**1,648.0**	**20.1**	**4.4**

Source: Stilwell, 2000.

9.6. Annex 5: Mapping of institutions working on climate change and health in SADC

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
Angola	NORAD http://www.norad.no/default.asp?V_ITEM_ID=11325	Climate change and environment	Funding for climate change and environment CC being considered a priority since the ratification of UNFCCC and active participation at the Bali meeting. Capacity in CC still weak	Norwegian government	Donor driven activities
Botswana	University of Botswana: Department of Environmental Sciences www.ub.bw	General	-Research priority setting -Motivating research on climate change -Networking scientists working on climate change -Facilitate dialogue between researchers and policy makers -Awareness creation	Various sources on a project basis	Network of Scientists as part of the Botswana Global Environmental Change Committee (BGECC)

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
	Botswana Meteorological Services http://www.weather.info.bw/entry_fs.html	General climatology	Monitors and analyses Botswana & regional weather, providing weather forecasts, bulletins and an extensive range of meteorological and climatologically data and reports. UNFCCC focal point UNFCCC National communication Modeling malaria transmission Mapping of malaria zones on basis of climate parameters	Government of Botswana	Government institution
	National Environmental Laboratory No website.	National policy and strategies	analyzes water, air and soil samples to determine and assess environmental pollution from sensitive areas such as polluted rivers, contaminated soils and gas emissions. Also serves as the national referral laboratory for	Initially funded by Norwegian government and later taken over by government	Government institution

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
			pollution control and prevention		
	University of Botswana: Harry Oppenheimer Okavango Research Centre (HOORC) www.orc.ub.bw	Livelihoods, ecosystems assessment, hydrological assessments and monitoring	Research Activities	Government of Botswana and various donors	University Research Centre
DRC					
Lesotho	Department of Meteorology Services: National Climate Change Programme http://www.lesmet.org.ls/AboutLMS.htm	Climatology	-general weather forecasts -Research on climate variability, climate controls, extreme weather events and quality assurance	Government of Lesotho	Government institution
	Lerotholi Politechnic www.lp.ac.ls	Civil engineering	Research on climate related issues	Government of Lesotho	Educational Institute
Madagascar	Université d'Antananarivo http://www.univ-antananarivo.mg	Teaching department	Vulnerability and Adaptation to Climate Change : Agricultural Systems in Madagascar	Funded by IDRC CCAA	Educational Institute
Malawi	Environment Affairs Department (EAD) www.**malawi**.gov.mw	Livelihoods, terrestrial ecosystems, Forestry, agriculture,	Spearheaded development of NAPA	Global Environment Facility and UNDP	Government Institution

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
		disaster management, early warning systems. Health not prioritized			
	University of Malawi: Faculty of Science				
	CURE, Malawi http://www.helpcurenow.org	Core business is to assist children living with disability but has been involved in adaptation to climate change activities	Review of the Disaster Risk Reduction policy Project on securing community resilience under a varying climate Enhancing the capacity of district planners in Blantre Plans to conduct institutional mapping of climate change in Malawi Contributed to the NAPA document	International organization with funding from various sources	International organization
	Action Aid www.**actionaid**.org.uk/655/**malawi**.html	Food security and water resources			
Mauritius	Friends of the Earth International www.foei.org	Livelihoods	Community based projects aimed at raising awareness	International NGO working closely with another NGO, Sigrid	Project

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
			and empowering communities	Rausing Trust	
Mozambique	Ministry of Coordination of Environmental Affairs (**MICOA)** www.micoa.gov.mz				
	Red Cross www.climatecentre.org	Disaster preparedness and response activities	Capacity building in disaster preparedness and response	Red Cross International	NGO activities on a project basis
	National Institute of Meteorology http://www.inam.gov.mz	General climatology	Monitoring weather in the country and for providing warning of imminent tropical storms or meteorological changes that could potentially threaten the country	Government of Mozambique	Government institution
	General Education Development (GED)				
	WWF, Mozambique http://www.panda.org	Conserving the world's biological diversity Ensuring that the use of renewable natural resources is sustainable Promoting the reduction of pollution and wasteful	Coral reef monitoring Integrating climate vulverability and adapation into coastal zone management policy and action plan Early warning for		

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
		consumption.	coastal agricultural communities		
Namibia					
Seychelles					
South Africa	Environmental Monitoring group (EMG) South South North (SSN) Indico – Development and Change (Indigo DC)	Food security	Promoting cultivation of wild rooibos plant	SSN Africa EMG Indigo DC	Project
	University of Cape Town: Climate Systems Analysis Group	All aspects of climate system	Development and running of several climate models and carrying out research in several areas climate change.	Various donors depending on type of project	Network
	University of the Free State http://www.uovs.ac.za		Implementing a project on managing Climate Risk to Agriculture and Water Resources in South Africa	Project funded by IDRC CCAA	
	Action Aid	Poverty and	Climate change	Various donors	NGO

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
	www.actionaid.org	HIV/AIDS	issues captured in strategic plan in the context of human rights		
	Agricultural Research Council (ARC) www.arc.agric.za	Food security	Two projects on climate change being implemented	Government of South Africa	Parastatal
	Witwatersrand University: Climate Research Group http://crg.bpb.wits.ac.za/html/about.html	Climate change is an overarching theme	Atmospheric aspects, microphysical processes, biogenic-atmospheric interactions and air quality	Government of South Africa	University
	Climate Systems Analysis Group (CSAG) www.csag.uct.ac.za	Water resources	Working on regional climate change scenarios	Various donors	Consortium of scientists in different university
	Council for Scientific and Industrial Research www.csir.co.za	Climate change and health Climate change and water Climate change and agriculture Climate change, ecological and economics Water and sanitation for development in the context of climate change	Multidisciplinary research	Government of South Africa and various donors	Parastatal Research Institute

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
		IWRM in the context of climate change			
	Department of Environmental Affairs and Tourism (DEAT)	All aspects	Lead national department for climate change issues	Government of South Africa	Government institution
	Environmental Monitoring Group (EMG) www.emg.org.za	Food Security			
	Government Committee on Climate Change (GCCC)	Crosscutting on all climate change issues		Government of South Africa	Government institution
	Environmental Modelling and Climate Change Natural Resources and Environment	Biogeochemistry, water, Biodiversity and health	Covers both climate and water and climate and health	Various donors under CSIR	Both institutional and network
	National Botanical Institute: Climate Change Group	Regional scale modelling of Climate Change	Covers regional aspects of climate change	Government of South Africa and other donors	Government institution
Swaziland	University of Swaziland www.uniswa.sz	Agriculture and food security	Study on community perspectives and policy response on climate change.	Government of Swaziland funding	University
Tanzania	Environmental Protection and Management Services (EPMS)	Strengthening the capacity of organizations in poor countries and supporting	A member of the Tanzania NAPA team CC awareness	Gets funding from providing services	Professional Environmental Firm

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
	http://epmstanzania.org	their initiatives in sustainable development	creation among community members Identification of CC vulnerability and poverty hotspots in Mt Kilimanjaro are Mangrove planting Intends to conduct institutional mapping		
	University of Dar es Salaam: Institute of Resource Assessment www.udsm.ac.tz		Project on strengthening Local Agricultural Innovation	Project done in collaboration with Malawi and funded by IDRC CCAA	
	WWF Tanzania http://www.wwf.org	Conserving the world's biological diversity Ensuring that the use of renewable natural resources is sustainable Promoting the reduction of pollution and wasteful consumption	Capacity building at community and government levels Information generation and sharing through the Global Climate Witness Programme Lobbying	Various donors	International organization

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
			CC adaptation geared towards ensuring ecosystems integrity Developing downscaled climate models of likely CC impacts in the region		
	National Institute of Medical Research (NIMRI) http://nimr.or.tz	Health aspects particularly those transmitted by vectors.	Health Research	Government of Tanzania and various donors	Government Institute
	Intercooperation, Tanzania http://www.intercooperation.ch	Development issues and climate change as a key element of development.	Aims at identifying and implementing new development ventures in Tanzania Began activities in climate change adaptation and mitigation in 1999 Hosts breakfast meetings on CC Collects experiences on adaptation from other countries Focal point for	A leading Swiss non-profit making organisation engaged in development and international cooperation since 1982	International Organization

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
			NGO forum on climate change in Tanzania Invited DANIDA and Swiss funding agencies to highlight their plans for climate change adaptation support at NGO Forum		
	Organisation for Economic Co-operation and Development http://www.oecd.org/countrieslis	Wide range of issues related to sustainable development	Provided guidance on how to mainstream responses to climate change within economic development planning and Assistance policies, with natural resource management as an overarching theme.	OECD uses its wealth of information on a broad range of topics to help governments foster prosperity and fight poverty through economic growth and financial stability.	International organization that works in partnerships with countries
Zambia	Zambia Meteorology Department www.meteo-zambia.net	General meteorology data	Provides country meteorology services	Government of Zambia	Government institution
	Energy and Environmental Concerns for Zambia (EECZ) www.hedon.info/Ene	Health	Piloting implementation of climate change and health	International Institute for Environment and Development (IIED) of London	Project

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
	rgyAndEnvironmentalConcernsForZambia		Implements the CLCC Cities and Climate change project activities Intends to establish a forum on CC for NGOs		
	Environment and Natural Resources Management Department (ENRMD) www.biodiv.be/zambia/convention/mtenr/enrmd	All aspects	Spearheaded the development of the National Adaptation Plan of Action (NAPA)	Global Environment Facility and UNDP	Government Institution
	University of Zambia http://www.unza.zm	Climatology, agronomy, livestock, fisheries.	Provided experts who prepared sectoral papers used for the development of NAPA	Global Environment Facility and UNDP	University
	Coperbelt University http://www.commonwealthed.org/cgi-bin/items.cgi	Health	Provided experts who prepared sectoral papers used for the development of NAPA	Global Environment Facility and UNDP	University
	Centre of Environment Engineering and Energy Zambia (CEEEZ) F.D.Yamba@ENG.U	Energy, water balance model, global circulation model.	Provided expert who prepared sectoral papers used for the development of NAPA	Global Environment Facility and UNDP	Consultants

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
	NZA.ZM				
	Ruralnet www.afdevinfo.com/htmlreports/org	Wildlife	Provided experts who prepared sectoral papers used for the development of NAPA	Global Environment Facility and UNDP	NGO
	Environmental Council of Zambia www.necz.org.zm	Covers cross-cutting themes	Spearheads the National Climate strategy	Government of Zambia and other donors	Government institution
Zimbabwe	Chiredzi Research Station	Agronomy			
	ZERO Regional Environment Organization, Zimbabwe http://www.suswatch.org	Mainly adaptation activities	Intends to carry out CC an institutional mapping with CARE and IFAD Awareness raising	Various donors	NGO
	CARE International www.**carezimbabwe**.org	Adaptation (livelihoods)	Projects on improving food security and livelihoods Projects on conservation farming, wetlands management, water point rehabilitation, providing relief to those vulnerable to drought, and disaster risk	Various donors	International NGO

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
			reduction Disaster preparedness		
	Midlands State University http://www.msu.ac.zw	Mainly teaching on agricultural issues	Building Capacity to Adapt to Climate Change in Zambia and Zimbabwe	Project funded by IDRC CCAA	University unit
	Matoposi Research Station Scientific, Industrial Research and Development Centre (SIRDC) University of Zimbabwe: Centre for Applied Social Science (CASS) Centre for International Forestry Research (CIFOR) Midlands State University http://www.undp.org/gef/adaptation/projects/CwD/	Climate Change, water and food security	Coping with drought and climate change	GEF funded	Consortium of researchers from various institutions
	University of Zimbabwe: Institute of Environmental Studies	Mainly training activities	Impacts and adaptation in climate change	Government of Zimbabwe and various donors	University Unit

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
	http://www.uz.ac.zw/ies		Prepared a working paper on Zimbabwe for the UNFCCC		
	University of Zimbabwe: University Lake Kariba Research Station (ULKRS) http://www.uz.ac.zw/ulkrs	Research on Natural Resources Management	Prepared a paper on CC impacts and human settlements in Africa,: prospects for adaptation Former Director (Magadza) is a member of the IPCC	Government of Zimbabwe and various donors	University Unit
	University of Zimbabwe, Institute of Development Studies (IDS) www.uz.ac.zw/units/**ids**	Mainly research on development issues	Research on the impacts of floods on livelihoods Project on food security improvement Lobbying on water harvesting improvement	Government of Zimbabwe and various donors	University Unit
	University of Zimbabwe: Faculty of Agriculture www.uz.ac.zw	Mainly teaching and research on agricultural issues	Implementing a project of resilience and the African Smallholder : Enhancing the Capacity of Communities to Adapt to Climate Change	Funded by IDRC CCAA	University unit

Country	Institutions	Theme of activities	Description of activities	Funding arrangements	Implementation strategy (programme, project, network, institutional specialization)
	University of Zimbabwe: Department of Physics www.uz.ac.zw	General climatology with little emphasis on climate change		Government of Zimbabwe and various donors	University Department

9.7. Annex 6: List of Networks

1. Capacity Strengthening of Least Developed Countries on Climate Change Adaptation (CLACC) http://www.clacc.net
2. Africa Center for Climate and Earth System Sciences (ACCESS) www.africaclimatescience.org
3. ACCCA project www.accaproject.org
4. Air Pollution Information Network for Africa (APINA) http://www.se/index.php?section=atmospheric&page=projdesc&projdescpage=9992
5. Regional Air Pollution In Developing Countries (RAPIDC) http://www.sei.se/rapidc
6. National Environmental Management Council (NEMC) http://www.nemctan.org
7. Southern African Nordic Centre http://www.sanord.org
8. Africa Center for Climate Earth System Science (ACCESS) www.africaclimatescience.org
9. Air Pollution Information Network for Africa (APINA) http://www.sei.se/index.php?section=atmospheric&page=projdesc&projdescpage=9992
10. Regional Air Pollution In Developing Countries (RAPIDC) http://www.sei.se/rapidc
11. Climate Systems Analysis Group http://data.csag.uct.ca.za
12. National Environmental Management Council (NEMC) http://www.nemctan.org
13. Southern African Nordic Centre http://www.sanord.org
14. African Climate Change Fellowship Programme (ACCFP)
15. African Technology Policy Studies Network (ATPS)
16. Global Climate Change Adaptation Network in Africa (in the process of being established)
17. Earth System Science Partnership-linked networks
18. Assessment of Impacts and Adaptation to Climate Change
19. National Global Change Committees
20. Pan African Start Secretariat (PASS)
21. Pages-Africa Network
22. African Pollen Database (APD) Network
23. Miombo Network
24. Kalahari Transect
25. Southern African Fire Network
26. East African Lakes (IDEAL)
27. AfriBasins and AfriCAT)
28. Afriflux
29. IGAC/DEBITS-AFRICA (IDAF)
30. Clobal Environmental Change and Food Security (GECAFS)
31. Climate Variability and Predictability (CLIVAR)

32. Global Energy and water Cycle Experiment (GEWEX)
33. Land Use and Land Cover Change (LUCC)
34. Other Human Dimensions of Global Change Research
35. The Consultative Group on International Agricultural Research (CGIAR)
36. CLIMAG (Climate and Agriculture in West Africa)

9.8. Annex 7: An example of the linkages between human health, climate change and ongoing stresses in coastal areas of Mozambique (Mozambique Initial National Communication Report, 2003)

Beira coast in Mozambique was identified as being the most vulnerable coastal area to sea level rise. It was established through modelling work that erosion and floods will be a major problem in year 2075. Sea level rise will result in an increase in the frequency and intensity of over-wash, flooding of the low relief features, erosion of the existing beach ridge beyond the sea wall and during high water of the spring tides severe inundation to an extent of about 42.5 km^2 along the coastline will be experienced. This will have major environmental and human health problems for example navigation channels will be affected by changes in water circulation and sediment distribution.

The increase of the temperature of the sea along the canal of Mozambique as a result of the El Niño phenomenon will have negative impacts on corals, which are an important part of the Mozambican marine ecosystem. Warming of the sea will affect the resurgence processes responsible for transporting nutrients from the deep layer of oceans to the surface for feeding the fish - thus affecting the fisheries and this has implications on income generation, malnutrition and eventually health.

10. Annex 8: An example of impact of climate change, food production and human health – fisheries in Namibia and the cold Benguela Current (Namibia Initial National Communication Report, 2002).

Namibia Fisheries are an important source of revenues, employment, and proteins and constitutes over 6% of Namibia's GDP (book et al., 2007). Commercial fishery is based on about 20 different species: along the shallower onshore waters on the continental shelf are small pelagic (open-water) species (pilchard, anchovy and juvenile mackerel) and lobster while in the waters further offshore are large pelagic species including adult mackerel, demersal (bottom- dwelling) hake and other deep-sea species, such as monkfish, sole and crab.

The Namibia fisheries rely on nutrient-rich upwellings of the cold Benguela Current. The upwelling is caused by the interaction of south-easterly winds with the north-flowing current and the topography of the seabed. Oxygen-poor water can accumulate near the sea-bed and suffocate marine life where upwelling is suppressed by northerly or easterly winds.

There is need to investigate changes in these ocean currents with large-scale climate phenomena such as ENSO since changes in the distribution and intensity of winds could have an effect on the fisheries sector. It has been noted that a trend of warmer SSTs since 1993 northern Benguela region has resulted in several environmental factors that have contributed to declining fish stocks in recent years, for instance the decline in pilchard stock.

Changes in the frequency, timing or distribution of the upwelling would influence production and this will influence protein intake on Namibia and other countries in the region that import fish form Namibia for instance, Botswana. It will also have a significant economic impacts given that marine fishery is the second largest export earner after mining in Namibia. Decline in fisheries will have implications on employment and income and general quality of life which eventually feed into health and wellbeing.