Centre for Occupational and environmental Health Research

Climate change and health in SADC region: Review of the current state of knowledge

Young T, Tucker T, Galloway M, Manyike P, Chapman A, Myers J

3 September 2010

Table of contents

EXECUTIVE SUMMARY

Climate change is affecting more than just physical infrastructure and economics as it is increasingly affecting basic natural life-support systems - safe drinking water, clean air, sufficient food, and secure shelter. The direct and indirect impact on health will be influenced by local environmental conditions, socio-economic circumstances, the extent of adaptations implemented to minimise the full range of threats to health and other modulating factors. The IPCC Working Group 2 report 2007 emphasises that the health impacts of CC will fall primarily on low-income, poorly resourced and geographically vulnerable populations.

This synthesis report was conducted on climate change and health in the Southern African Development Community (SADC) region in order to contribute to informed debate and the development of future climate change research, adaptation, surveillance and education programmes in the SADC region.

Evidence shows that the SADC region is experiencing increasing frequency of hot days and decreasing frequency of extremely cold days. Rainfall trends are variable but evidence points to an increased inter-annual variability, with extremely wet periods and more intense droughts in different countries. Projections show that changes will not be uniform over the region with the central, southern land mass extending over Botswana, parts of north western South Africa, Namibia and Zimbabwe being likely to experience the greatest warming of 0.2°C to 0.5°C per decade. Frequency of extremely dry winters and springs will increase to roughly 20%, while the frequency of extremely wet summers will double. Warming is also predicted to increase the frequency and intensity of tropical storms in the Indian Ocean.

The region is vulnerable to the impact of climate change due to poverty, high pre-existing disease burden, fragmented health services, and water and food insecurity. No substantial studies assessing the association between climate change and health in the SADC region have been conducted. Where research has been conducted, it focused on infectious diseases - particularly malaria - and little work had been done on attributing disease burden to climate change and evaluating strategies to adapt to climate change. Furthermore, an overview of health considerations in the National Adaptation Programmes of Action for climate change in least-developed countries and small island states found that health was not seen as a priority, as most activities focused on biodiversity and agricultural activities.
Very few institutions specialising in climate change and health were identified in the SADC region.

Comprehensive planning and action to address climate change in the SADC region needs to be intersectoral, to draw on local data and scenarios, and involve local and regional authorities and health care providers.

ABBREVIATIONS

CBD	United Nations Convention on Biological Diversity
CCD	United Nations Convention to Combat Desertification
CO_2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disease
CVS	Cardiovascular system
DFID	Department for International Development
BoD	Burden of Disease
ENSO	El Niño/La Niña-Southern Oscillation
GDP	Gross Domestic Product
GEC	Global Environmental Changes
GHG	Green House Gases
HDI	Human Development Index
IPCC	Intergovernmental Panel on Climate Change
MDGs	Millennium Development Goals
NAPA	National Adaptation Programs of Action
RCCP	Regional Climate Change Programme
SADC	Southern Africa Development Community
STIs	Sexually transmitted infections
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation

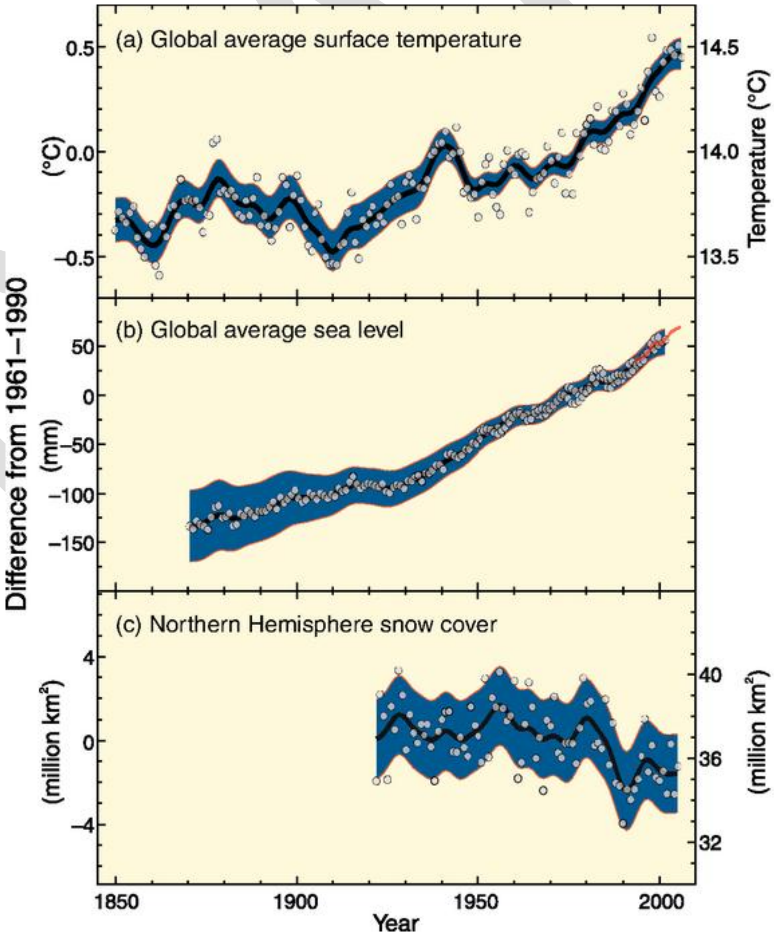
1. BACKGROUND

1.1 CLIMATE CHANGE

Economic activities increase the emission of greenhouse gases (GHG). This human-induced climate change is one of the 'global environmental changes' (GEC). Raised carbon dioxide (CO_2), methane, and other GHG increase the heat-trapping capacity of the lower atmosphere resulting in global warming.

Climate change is presenting with raised surface temperature (Fig. 1) with more dry days and an increased number of hot nights per year. The Intergovernmental Panel on Climate Change (IPCC) http://www.ipcc.ch/, a scientific intergovernmental body established in 1988 and tasked with evaluating the risk of climate change caused by human activity, projects that this will influence weather patterns (IPCC 2007), causing an increased frequency and intensity of extreme events (extreme heat, severe storms, droughts, and floods). Furthermore, a rise in sea levels is the consequence of thermal expansion of ocean water and the melting of land-based glaciers and ice-sheets (Figure 1). The global average sea level rose at an average rate of 1.8 ± 0.5 mm per year between 1961 to 1990, and at an average rate of about 3.1 ± 0.7 mm per year from 1993 to 2003 (IPCC 2007). Rainfall patterns have changed with some regions experiencing increases while others had decreases in rainfall.

Figure 1: Changes in temperature, sea level and Northern Hemisphere snow cover



Source: http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains1.html

Key strategies to address climate change include mitigation and adaptation. Mitigation (i.e. primary prevention of climate change) focuses on the reduction in GHG emissions and modified land-use, while adaptation measures aim to lessen the impact of climate change (IPCC 2007). International treaties related to climate change are summarised in Table 1.

Table 1: Summary of international climate change treaties

United Nations Framework Convention on Climate Change (UNFCCC) http://unfccc.int/2860.php	An international environmental treaty with the main objective: *"…the stabilization of GHG concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."* The UNFCCC allows for the introduction of protocols to the Convention. ○ Kyoto Protocol http://unfccc.int/kyoto_protocol/items/2830.php - came into force on 16 February 2005 following ratification by Russia. Under the Protocol, 37 industrialised countries commit themselves to a reduction of four GHG (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride) and two groups of gases (hydrofluorocarbons and perfluorocarbons) produced by them.
United Nations Convention to Combat Desertification (CCD) http://www.unccd.int/	"*To combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification*" Came into force December 1996.
United Nations Convention on Biological Diversity (CBD) http://www.cbd.int/	Signed by 150 government leaders at the 1992 Rio Earth Summit, the Convention on Biological Diversity is dedicated to promoting sustainable development.
Montreal Protocol http://www.unep.org/ozone/pdfs/montreal-protocol2000.pdf	An international treaty designed to protect the ozone layer by phasing out the production of a number of substances believed to be responsible for ozone depletion. Came into force January 1989.

Despite the adoption of these conventions by many countries, *"Recent observations confirm that, given high rates of observed emissions, the IPCC worst-case scenario trajectories (or even worse) are being realized. For many key parameters, the climate system is already moving beyond the patterns of natural variability within which our society and economy have developed and thrived. These parameters include global mean surface temperature, sea-level rise, ocean and ice sheet dynamics, ocean acidification, and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts."*

Climate Congress, Copenhagen, March 2009

1.2 CLIMATE CHANGE AND HEALTH

Climate change is affecting more than just physical infrastructure and economics as it is increasingly affecting basic natural life-support systems. It affects the fundamental requirements for health - safe drinking water, clean air, sufficient food, and secure shelter and has many adverse health impacts (IPCC 2007). The impact on health results directly from extreme weather events (e.g. heat waves and floods) and indirectly from socially mediated risks (e.g. displacement, conflict, damaged infrastructure, crop failure) and/or ecologically mediated risks (e.g. food, water, vectors) (McMichael 2010).

The World Health Organisation (WHO) developed standardised comparative risk assessment methods for estimating aggregate disease burdens attributable to different risk factors which have been applied to existing and new models for a range of climate-sensitive diseases in order to estimate the effect of global climate change on current disease burdens and likely proportional changes in the future (Campbell-Lendrum & Woodruff 2006). They estimated that the extent of climate change by the year 2000 (relative to the 1961-1990 average climate) was estimated to have caused, worldwide during that year, approximately 160 000 deaths and the loss of 5 500 000 disability-adjusted life-years from malaria, malnutrition, diarrhoeal disease, heat waves and floods (Campbell-Lendrum & Woodruff 2006, McMichael 2010).

To comprehensively consider the impact of climate change, we have drawn from existing models developed by McMichael (2003) and Eisenberg (2007) and present an adapted model which is discussed in the following section. In assessing the health impact of climate change one must, however, be mindful that the effects of climate change are complex, and often interact with other distal determinants of health (Eisenberg 2007) and global environmental changes (McMichael 2010) (Fig. 2).

Figure 2: Global environmental changes: pathways and health risks (McMichael 2010)

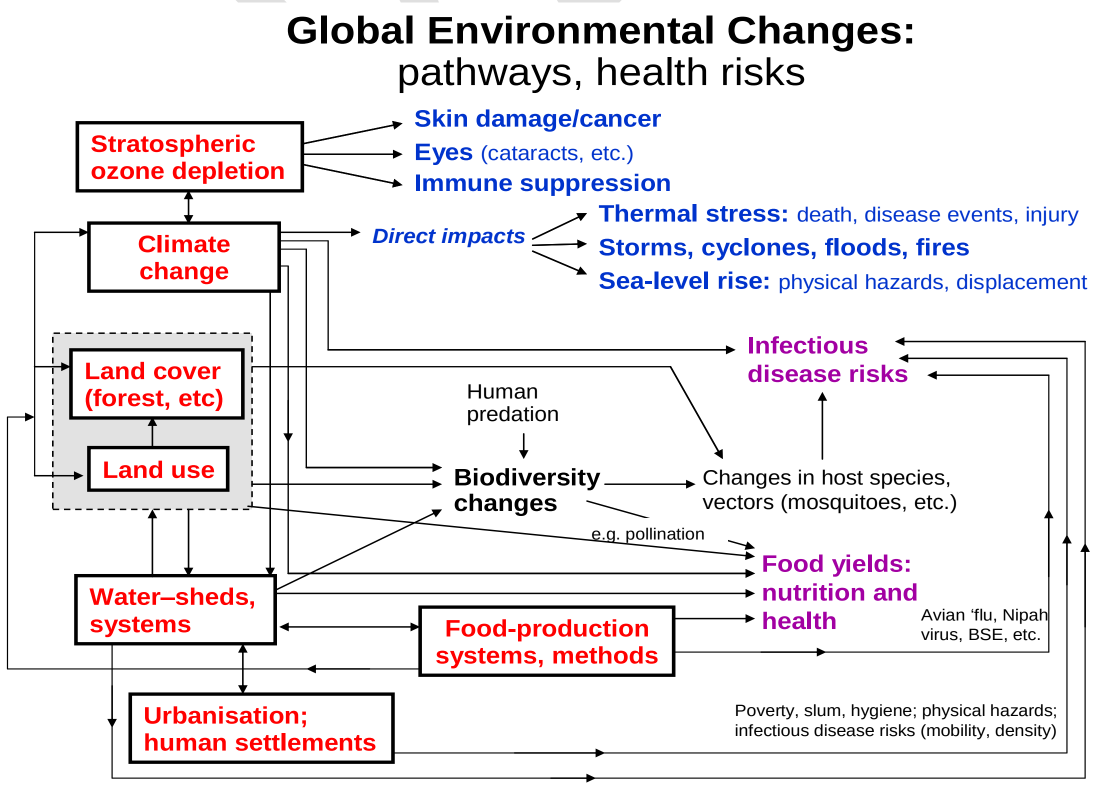
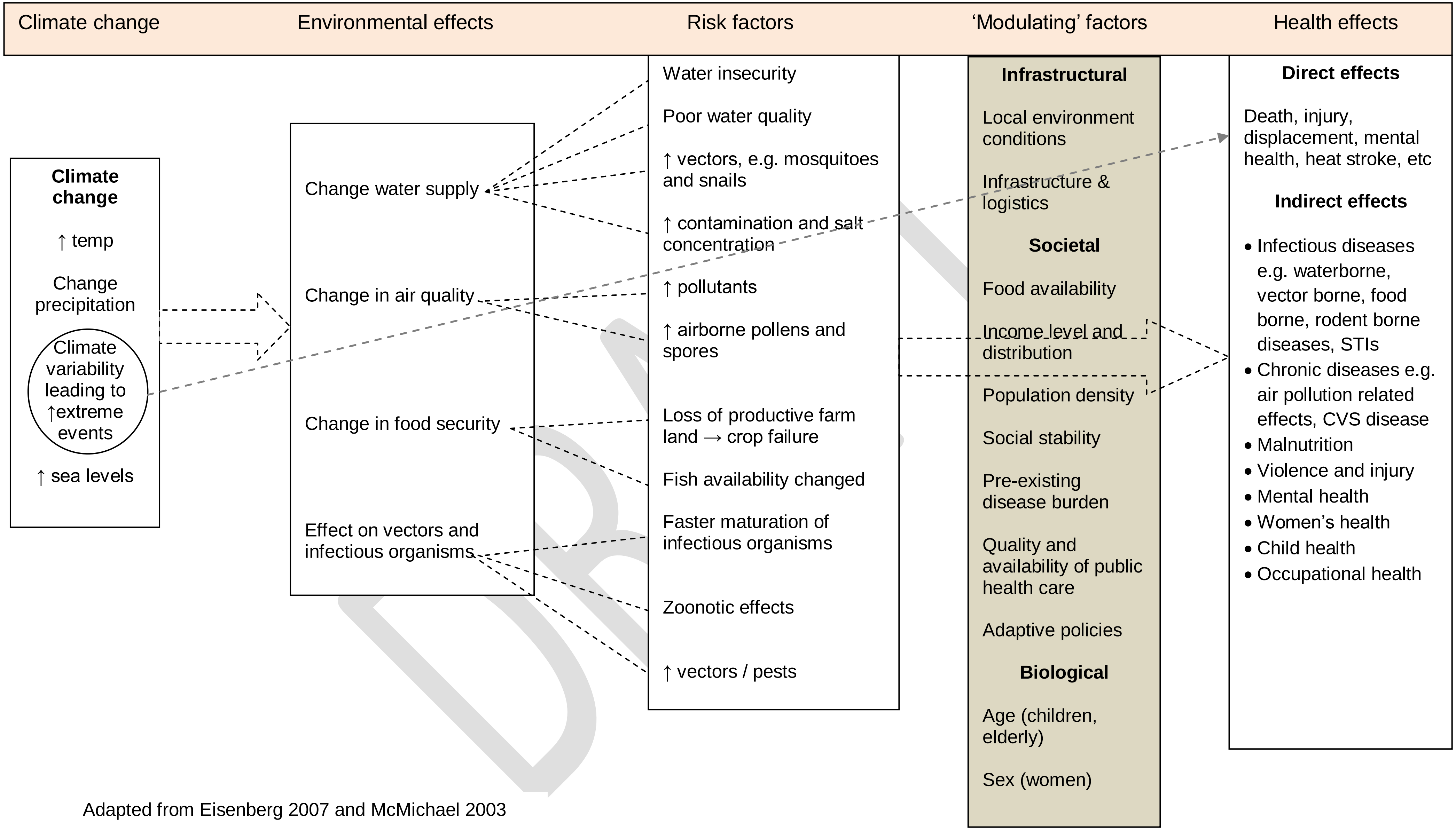


Figure 3: Impact of climate change on health



Adapted from Eisenberg 2007 and McMichael 2003

Environmental effects of climate change and risks to health

Environmental effects of climate change include change in water supplies, change in air quality and food security, and direct effects on vectors (Fig. 3).

Change in water supply

Climate change aggravates water insecurity (McMichael 2009). Change in rainfall results in an increased frequency and severity of droughts in certain areas, and floods in others. Scarcity of water negatively impacts on crop and pasture yields, and also affects vector populations at the larval and adult stages. For instance, since many *anopheline* vectors of malaria breed in small, natural pools of clean water, droughts usually result in decreases in vector populations and transmission due to the reduced number and quality of vector breeding sites (Gage 2008). However, the impact of changes in precipitation patterns on malaria transmission is dependent on the ecology of the vector species (Gage 2008). In Africa specifically, the change in rainfall will affect the densities of *Anopheles gambiae* more quickly, a species that breeds in smaller water sources than those utilised by *An. funestus*, which can breed on the edges of larger bodies of water (Gage 2008). See section below on infectious diseases and vectors.

Flooding destroys essential infrastructure (houses, roads, schools, power supplies, etc.) and results in population displacement. Heavy rains can also lead to storm water discharge of contaminants into water sources (Patz 2008). This can be compounded by discharge of untreated sewage mixed with storm water into water sources (Patz 2008).

Water scarcity also results in higher concentrations of salt and chemical contaminants in the water (McMichael 2009). Furthermore, rising sea levels result in salination of freshwater supplies, loss of productive farm land and changes in breeding habitats for coastal dwelling mosquitoes (McMichael 2009).

Change in air quality

Higher temperatures also affect the formation and dispersal of various air pollutants. Ozone, a major urban air pollutant in the lower atmosphere, forms more readily at higher temperatures from air-pollutant precursors (McMichael 2009). The range, concentration and seasonality of pollens and spores (‘aeroallergens’) are also affected by temperature, rainfall and humidity (McMichael 2009).

Change in food security

Global food yields are predicted to be negatively affected by climate change. This impact will, however, be unevenly distributed. Countries where both warming and reduced rainfall are likely to occur are at greatest risk (McMichael 2009).

Fish populations important to local food security are expected to move to higher latitudes which will affect protein supplies and livelihoods in coastal communities. This effect will be exacerbated by effects of coral reef damage, warmer waters, acidification (due to increasing uptake of CO_2) and decreased consistency of river flows (McMichael 2009).

Effect on infectious organisms and vectors

In warmer conditions, bacteria in food and in nutrient-loaded water multiply more rapidly, and infectious agents within mosquitoes (e.g. malaria plasmodium, dengue virus) mature more quickly (McMichael 2009). While there is evidence of these increased replication rates in mosquitoes, it is unclear whether this is translating into increased incidence and mortality of malaria in human populations (Byass 2009). Zoonotic diseases that extend into human populations from animal sources, are also affected by climate-related changes in the density and movement of the 'reservoir' animal species (for example, Rift Valley Fever (Kenya: cattle) (McMichael 2009).

In warmer conditions, rodents, flies and other pests increase in numbers. Mosquitoes reproduce more efficiently and must feed more often (Gage 2008, McMichael 2009). Surface water patterns also influence mosquito breeding and humidity affects mosquito survival (Gage 2008, McMichael 2009). Furthermore, the distribution of vectors also changes as a result of local warming – for example, the northwards extension of the vector tick for tick-borne encephalitis in Sweden over the past two decades, the northwards extension of the water snail that spread schistosomiasis in eastern China, and the ascent of highland malaria to higher altitudes in parts of eastern and southern Africa (Gage 2008, McMichael 2009).

'Modulating' factors

Complicated relationships exist between climate change and health which are difficult to model in a fully integrated manner. Health risks at different levels may impact on health directly and indirectly and also influence each other (Frumkin & McMichael 2008). Those listed in the column of modulating factors range from distal to proximal health determinants and include infrastructural, social, behavioural and biological risks (Fig. 3). They may behave as confounding, effect-measure modifying; or mediating variables in the relationship of principle interest between climate change and health outcomes. More fully integrated modelling would seek to include these variables in more complex multi-level modelling examining specific hypotheses about causal pathways.

The actual health impacts will be strongly influenced by local environmental conditions, socio-economic circumstances and biological factors as well as the range of social, institutional, technological and behavioural adaptations implemented to reduce the impact on health. This impact will thus vary by region and will disproportionately affect certain populations. This makes geographic scale important when considering climate change information which should ideally be available in a relatively fine-grained matrix and in time series.

<u>Infrastructural</u>

Coastal, urban, low-lying areas, islands and vector border regions will be affected more than other areas (Hess 2008). In addition, the quality of water and sanitation, along with roads and transport logistics to cope with disaster management and changes in population needs influence the impact of climate change.

<u>Societal</u>

Food-insecure countries that are already facing hunger and malnutrition will be more affected by reduced crop and pasture yields as a result of climate change. The economically disadvantaged will also be more affected, e.g. farmers working on a large-scale will be able to implement mechanisms to adapt to changing climate, however, the poor subsistence farmers will be unable to afford the necessary modifications and adaptation (Ramin 2009, St. Louis 2008). To this end, women and children will be extremely vulnerable, as described below.

Crop and pasture failure can cause conflict over access to farm land, and other scarce resources. Climate change may exacerbate already politically complex and conflictual situations/regions.

Individuals with chronic diseases are more vulnerable to the effects of heat and air pollution (McMichael 2009). Immuno-compromised patients are also more vulnerable to infectious diseases and other consequences of climate change.

Public health responses play a central role in addressing the impact of climate change (Frumkin 2008). Essential public health services, as described by Frumkin (2008) include:

- Monitoring the health status to identify and solve community health problems, e.g. tracking of diseases and trends related to climate change.
- Diagnosing and investigating health problems and health hazards in the community, e.g. investigation of infectious water-, food-, and vector-borne disease outbreaks.
- Informing, educating, and empowering people about health issues, e.g. informing the public and policymakers about health impacts of climate change.
- Mobilising community partnerships and action to identify and solve health problems, e.g. public health partnerships with industry, other professional groups, faith community, and others, to craft and implement solutions.
- Developing policies and plans that support individual and community health efforts, e.g. municipal heat-wave preparedness plans.
- Linking people to needed personal health services and ensuring the provision of health care when otherwise unavailable, e.g. health care service provision following disasters.
- Ensuring competent and available public and personal health care workforces, e.g. training of health care providers on health aspects of climate change.
- Evaluating effectiveness, accessibility, and quality of personal and population-based health services, e.g. programme assessment of preparedness efforts such as heat-wave plans.
- Researching new insights and innovative solutions to health problems, e.g. research on health effects of climate change, including innovative techniques such as modelling, and research on optimal adaptation strategies.

Therefore, the quality, availability and readiness of public health care, as well as emergency medical (Hess 2009) and other services are important services which can address the impact of climate change (Frumkin 2008, Keim 2008).

The level and extent of implementation of adaptive projects to reduce the impact on health will influence climate change effects.

Biological

Children, (pregnant) women and the elderly are more vulnerable to infectious diseases, malnutrition, heat-related illnesses, water insecurity, extreme events, effects of air pollution and injury (Balbus 2009, Kistin 2010, Luber 2008, Ramin 2009, Shea 2007).

Women are less empowered than men in almost all societies and, as a result, are affected more than men during natural disasters – more women are killed or killed at a younger age than men (WHO 2005). The difference is influenced by the socio-economic status of women, as the effect is worse in countries where women have a very low social, economic and political status. Pregnant women are also particularly vulnerable to various infectious diseases, including malaria and hepatitis E. Furthermore, fuel and water shortages increase women's workload where they are responsible for its collection (Rain 2009, WHO 2005).

Health effects

Climate change will have many adverse health impacts (Fig. 3). It has been argued that it is unlikely that there will be any/many entirely new adverse health outcomes, but rather a worsening of existing health problems, through a change in patterns (McMichael 2009). It is also notable that there may be some beneficial effects in discrete regions (IPCC 2007, McMichael 2009). In some countries, for instance, warmer winters may reduce the number of temperature-related deaths and other health events, as exposure to very cold conditions decreases (McMichael 2009).

Direct effects

There is an increased risk of death, injury, and population displacement as a result of extreme climate events such as fires, droughts, hurricanes and floods (McMichael 2009). Associated with this are anxiety, post-traumatic stress disorder and depression, and other mental health conditions, resulting from trauma, loss of loved ones and property, and displacement (Berry 2010, McMichael 2009).

Prolonged exposure to high temperatures can cause heat-related illnesses such as heat cramps, heat syncope, heat exhaustion, heat stroke and death (Luber 2008). More frequent and intense heat waves are therefore associated with an increased morbidity and mortality (Luber 2008). The elderly and people with pre-existing medical conditions (e.g. cardiovascular disease, psychiatric conditions) and those on medication which impact on the salt and water balance are at great risk for heat-related illness and death (Luber 2008). Drinking alcoholic beverages, ingesting narcotics and participating in strenuous outdoor activities, e.g. manual labour in hot weather, which is a feature of much work in the developing world during summer, are also associated with heat-related illnesses (Luber 2008). Temperature extremes also affect physiological functioning, mood, behaviour (accident-proneness, aggressiveness) and workplace productivity, especially in outdoor workers (e.g. subsistence farming) and those working in poorly ventilated, hot factory conditions (Kjellstrom 2009, Tawatsupa 2010) (see section below on occupational health).

Chemical and biological effects of air pollutants and allergens can cause an increase in deaths from asthma and in those with pre-existing chronic lung disease (McMichael 2009).

Indirect effects

Infectious diseases

- Waterborne (enteric diseases) - Changes in rainfall patterns affect river flows, flooding, sanitary conditions and the spread of diarrhoeal diseases, including cholera, as well as other enteric diseases caused by enteroviruses, hepatitis A and E. Heavy runoff after severe rainfall can also contaminate recreational waters and increase the risk of human illness through higher bacterial counts. This association is strongest at beaches closest to rivers. Ear, nose, and throat; skin, respiratory and gastrointestinal illnesses are commonly associated with recreational swimming in fresh and oceanic waters. Other diseases include hepatitis, giardiasis, and cryptosporidiosis (Patz 2008).

- Vector borne -
    - Malaria (*Plasmodium vivax*, *P. falciparum*) – Climate factors which impact on the malaria burden and distribution include temperature, rainfall, and humidity. These impact on disease distribution; faster pathogen development within the vector; development, reproduction, activity, distribution, and concentration of vectors; transmission patterns and intensity; and outbreak occurrence (Gage 2008).
    - Dengue fever (Dengue virus) – Temperature and rainfall impact on outbreaks, mosquito breeding, concentration of vectors, and transmission intensity (extrinsic incubation period) (Gage 2008).

- Tick-borne encephalitis (Ixodes species ticks and flaviridae) – Temperature and rainfall as well as humidity impact on the vector (ticks) distribution (Gage 2008).
- Plague (*Yersinia pestis*) - Temperature, rainfall, humidity and El Niño–related events impact on the development and maintenance of pathogen in the vector (flea); survival and reproduction of vectors and hosts; occurrences of historical pandemics and regional outbreaks, and the distribution of disease (Gage 2008).

- Food borne - Studies in the UK, Australia and Canada demonstrated a relationship between short-term (e.g. weekly) high temperatures and the rate of occurrence of salmonella food-poisoning (Ebi 2008).

- Sexually transmitted infections (STIs) – population displacement, poverty and dislocated communities are associated with increased levels of STIs. This manifests in many ways, including gender violence, transactional sex, commercial sex work, increased partner numbers, and increased risk-taking behaviours.

Chronic diseases

There is an increased risk of respiratory illnesses from the higher ground-level ozone and other air pollutants. Exacerbation of asthma, chronic obstructive pulmonary disease (COPD) and other respiratory allergic conditions is associated with increases in airborne pollens and spores. Furthermore, cardiovascular system (CVS) disease (e.g. cardiac failure, stroke) also worsen as a result of worsening air pollution, and renal disease is associated with heat waves (for example, kidney stone disease associated with dehydration and increased hospitalizations for acute renal failure) (Kjellstrom, Butler, Lucas & Bonita 2009)

Malnutrition

Increased risk of malnutrition from impaired/failed agriculture (and from associated impoverishment from loss of rural livelihoods). The WHO's estimate of disease burdens already attributable to climate change in the year 2000 identified malnutrition as the pre-eminent component of health loss (Campbell-Lendrum and Woodruff 2006). Most of that estimated loss (via premature deaths, stunting and disabling infection) was in young children in developing countries.

Violence and injury

As a consequence of worsening climate and environmental conditions, there will be increased immigration and refugee pressures on the environment on neighbouring countries. The demographic disruption and associated social tension will be associated with adverse health effects which include increased interpersonal violence (McMichael 2009). In addition, damaged transport infrastructure and poor weather conditions may increase the incidence and severity of motor vehicle-related crashes.

Mental health

Mental health diseases can result from direct (as discussed above) or indirect climate change impacts. Anxiety and depression as a result of long-term impact of displacement, loss of family members, disabling injuries and increased mental health risks such as post-traumatic stress disorder associated with extreme weather events or depression/suicide associated with impoverishment or lost livelihood (e.g. long-term drying in rural regions) or displacement are indirect consequences of climate change (Berry 2010). Substance

(especially alcohol) misuse and abuse are also more prevalent amongst displaced populations and populations subject to extreme environmental or climatic stressors.
Women's and child health

As discussed earlier under biological factors, women and children are more vulnerable to effects of heat, water insecurity, extreme events, malnutrition, and infectious diseases (Balbus 2009, Kistin 2010, Luber 2008, Ramin 2009, Shea 2007). Women's lower social standing within communities results in a greater economic stress and resultant direct and indirect health impact from climate changes.

Occupational health

Physical hazards due to temperature extremes can cause heat illness and loss of productivity (especially given that most subsistence agriculture takes place in hot parts of the globe where there is no possibility of air conditioning) or cold injury and loss of productivity due to encumberment with many layers of clothing (Kjellstrom 2009; Kjellstrom, Holmer and Lemke 2009). Chemical hazards from the effect of wild fires in dry, hot conditions or smog in cold weather with temperature inversions can have serious cardio-respiratory effects. There are also impacts of stressful social and environmental conditions. Emergency and health personnel are particularly at risk from these as well as biological (infectious) hazards.

1.3 SADC REGION, CLIMATE CHANGE AND HEALTH

The section of this report immediately above deals with what is known about climate change and health and has principally, but not exclusively, a developed world perspective. The rest of this report looks at the application of global knowledge to the Southern African Development Community (SADC) context.

The Regional Climate Change Programme (RCCP) is a SADC-wide programme funded by DfID to facilitate the strengthening of adaptive capacity and resilience to climate change across the SADC region. It is the purpose of the RCCP to hold a meeting about potential health effects of Regional Climate Change during the first week of October 2010. The purpose of the meeting is to obtain stakeholder input and agreement amongst health experts on the direction of desirable and appropriate responses and activities related to climate change and health in the SADC region. Once this understanding is in place, the RCCP can further solidify its research direction on the impacts of climate change and human health.

To inform these future initiatives it is important to understand climate change and health in the SADC region, review and synthesise what has been done to date in the SADC region, and, in order to avoid duplication and establish collaborative projects, to identify organisations/networks conducting work related to climate change in the region.

2. AIM AND OBJECTIVES

Aim

To conduct a review on climate change and health in the SADC region in order to contribute to informed debate and development of future climate change and health research, adaptation, surveillance and education programmes in the SADC region.

Objectives

The objectives of this synthesis report are:

a. To provide a synthesis of the current state of knowledge and gaps of direct and indirect impacts of climate change on health in the SADC region.

   i. Direct climate-related determinants of health
   ii. Indirect climate-related determinants of health
   iii. Focusing on the patterns of important health outcomes for the SADC region likely to be impacted by climate change

b. To provide a synthesis of national, regional and international initiatives or institutions engaged in activities focused on climate change related to health in the SADC region.

3. METHODS

3.1 To inform the synthesis of the current state of knowledge and gaps of direct and indirect impact of climate change on health in the SADC region, a literature review was conducted.

Sources of data included:

- RCCP
- Burden of disease data
- Published papers on climate change and health including descriptive and analytic studies identified via MEDLINE, grey literature and personal communication with experts such as Anthony McMichael, Paul Epstein, Peter Byass and others in the field
- Methodological papers on the analytic approaches on how to examine climate change and health
- Existing policy documents and unpublished reports

Project team members selected relevant materials from informed sources for inclusion. Relevant papers were then summarised.

3.2 In order to provide a synthesis of national, regional and international initiatives or institutions engaged in activities focused on climate change related to health in the SADC region, a detailed list of key institutions and relevant stakeholders to contact was compiled. To avoid duplication, this list was compared with organisations and institutions contacted by Dube (2009) and those institutions and stakeholders not included/covered by Dube (2009) were then contacted by email to request information (Appendix A). Activities were grouped into:

Awareness raising
Research including generation and identification of data sources
Assessing impact
Adaptation
Monitoring
Education/training

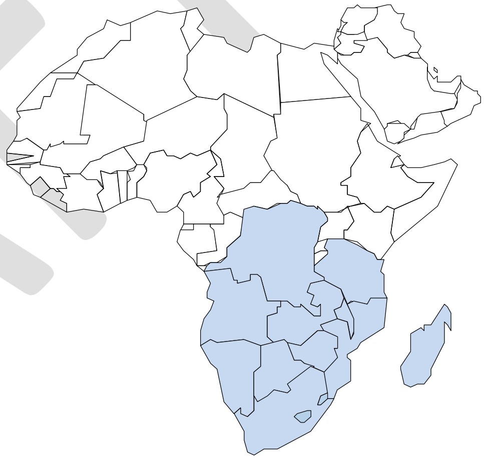
4. FINDINGS

The Regional Climate Change Programme (RCCP) focuses work around major themes namely water, food security, and disaster risk and response. This section is structured to link with the model (Fig.3), discussed in section 1.2 of the report, which comprehensively looks at the impact of climate change on health. The following table shows how the findings section relates to the major RCCP thematic areas.

RCCP thematic area	Relevant findings section
Water	4.2.1, 4.2.3
Food security	4.2.1, 4.2.2
Disaster risk and response	4.2.1, 4.2.3

4.1 CLIMATE CHANGE AND HEALTH IN THE SADC REGION

The Southern African Development Community (SADC) http://www.sadc.int/ was established in Windhoek, on 17 August 1992, replacing the Southern Africa Development Coordination Conference (SADCC) of 1980. Current SADC Member States include Angola, Botswana, the Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, United Republic of Tanzania, Zambia and Zimbabwe. The region has a wealth of natural resources which are, however, unevenly distributed and the economies of the region are heavily dependent on its natural resources and foreign aid.



The Human Development Index (HDI), a composite statistic of life expectancy, education and per-capita gross domestic product (GDP), ranges from 0.39 to 0.80 compared to developed countries with HDI above 0.90. Poverty is one of the greatest challenges facing the region (SADC international conference on poverty & development 2008). Table 2 presents some of the key economic and demographic indicators.

Table 2: SADC region economic and demographic indicators

Country	GDP, 2004 (Billions of U.S. $)	Real GDP Growth Rate, 2004 Estimate	Real GDP Growth Rate, 2005 Projection	Per Capita GDP, 2004	Population 2004 (Millions)
Angola	$20	12.2%	14.4%	$1,381	14.8
Botswana	$9	5.4%	4.8%	$4,852	1.7
Democratic Republic of Congo	$6.0	5.7%	6.0%	$110	54.8
Lesotho	$1.5	4.4%	4.8%	$682	2.1
Madagascar	$3.7	4.7%	5.5%	$211	17.4
Malawi	$2.8	3.6%	4.5%	$248	11.2
Mauritius	$6.3	4.1%	4.3%	$5174	1.2
Mozambique	$6.0	7.3%	6.1%	$305	19.2
Namibia	$5.0	4.4%	3.8%	$2,524	1.9
Seychelles	$0.7	-2.0%	0.5%	$8,348	0.1
South Africa	$213.1	3.7%	4.0%	$4,562	46.7
Swaziland	$2.0	2.1%	1.8%	$1,772	1.1
Tanzania	$11.0	5.7%	5.8%	$266	42.1
Zambia	$5.0	4.6%	4.8%	$489	10.7
Zimbabwe	$3.9	-4.3%	-1.4%	$296	13.2
Regional Total/Average	*$296.4*	*4.0%*	*4.5%*	*$1,985*	*238.8*

Source: http://www.eia.doe.gov/emeu/cabs/sadc.html

Burden of disease

It is important to understand the baseline burden of disease (BoD) in southern Africa, so as to estimate the impact of climate change on these existing levels. SADC countries are faced with a quadruple burden of disease resulting from emerging infectious diseases (e.g. HIV/AIDS), old infectious diseases (e.g. tuberculosis), chronic diseases (e.g. asthma, chronic obstructive pulmonary disease (COPD), hypertension, ischaemic heart disease and diabetes), and intentional and unintentional injury. The neonatal mortality rate ranges from 7 to 54/1000 live births, infant mortality rate (IMR) from 14 to 116/1000 live births, adult mortality rate from 157 to 725/1000 population and maternal mortality ratio from 15 to 1400/100 000 live births (Table 3) (WHO 2009). In the African region, life expectancy at birth for both sexes is 52 years and the healthy life expectancy at birth (average number of years that a person can expect to live in 'full health' by taking into account years lived in less than full health due to disease and/or injury) is 45 years compared to 80 years and 70 years in high-income countries respectively (WHO 2009).

Table 3:SADC region: mortality rates (WHO 2009)

Country	Neonatal mortality rate per 1000 live births (2004)	Infant mortality rate (probability of dying between birth and age 1 per 1000 live births) (2007)	Under-5 mortality rate (probability of dying by age 5 per 1000 live births) (2007)	Adult mortality rate (probability of dying between 15 and 60 years per 1000 population) (2007)	Maternal mortality ratio (per 100 000 live births)
Angola	54	116	158	347	1400
Botswana	46	33	40	514	380
DRC	47	108	161	357	1100
Lesotho	52	68	84	725	960
Madagascar	41	70	112	264	510
Malawi	26	71	110	544	1100
Mauritius	9	15	17	157	15
Mozambique	35	115	168	498	520
Namibia	20	47	68	365	210
Seychelles	7	14	16	172	-
South Africa	17	46	59	520	400
Swaziland	40	66	91	618	390
Tanzania	35	73	116	472	950
Zambia	40	103	170	550	830
Zimbabwe	36	59	90	713	880

The region has a longstanding high rate of malnutrition, HIV/AIDS, malaria and tuberculosis (TB). The prevalence of HIV among adults aged ≥15 years is as high as 24% in certain populations, with TB prevalence as high as 812/100 000 population (WHO 2009). TB prevalence has increased substantially in the communities which bear the greatest burden of HIV/AIDS. The percentage of children aged <5 years underweight for age ranges from 6.1 to 36.8% (WHO 2009). Furthermore, the prevalence of chronic diseases is expected to increase significantly over the next few years - the number of people with diabetes, for example, is predicted to increase by 80% from 10.4 million to 18.7 million by 2025 (Mash 2007).

Burden of disease information exists at country, regional and global levels and has made it possible to assess risk attributable to different risk factors, including climate change, on different groupings of disease burden thought to be sensitive to climate change. However, this burden of disease data are extremely poor throughout Africa. Campbell-Lendrum and Woodruff (2006) have applied standardised comparative risk assessment methodology to estimate the impacts of climate change globally. In South Africa considerable work on the impact of various risk factors on BoD has been studied by the South African Comparative risk Assessment Collaborating Group (Bradshaw 2007, Bradshaw & Norman, *et al*. 2007, Groenewald 2007, Johnson 2007, Joubert 2007, Joubert & Norman, *et al.* 2007, Nannan 2007, Norman & Bradshaw, *et al.* 2007, Norman & Cairncross, *et al.* 2007, Norman & Matthee, *et al.* 2007, Norman & Barnes, *et al.* 2007, Norman & Gaziano, *et al*. 2007, Lewin & Norman, *et al.* 2007, Nojilana 2007, Schneider 2007). Some of the health outcomes are directly related to those included by Campbell-Lendrum & Woodruff (2009).

The SA Medical Research Council Burden of Disease Research Unit, led by Professor Bradshaw, has also conducted BoD research on a smaller scale for the Western Cape Province of South Africa showing a relatively similar picture to the national priority list of both contributors to, and predictors of, various burden of disease components. Similarities were found despite the more developed character of the Western Cape Provincial society and economy. Furthermore, studies conducted for the Western Cape Provincial Government

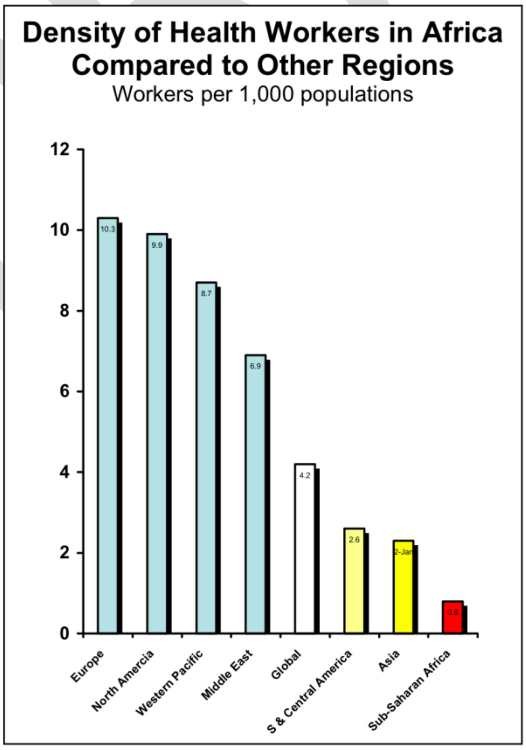
Department of Health dating from 2005 have examined a range of preventive interventions aimed at reducing burden of disease components for evidence of effectiveness and local appropriateness (Western Cape Burden of Disease Reduction Study 2007 & 2008).

For SADC countries in the Southern African region, the WHO has BoD data which are highly derivative from a small number of sources which are unlikely to be nationally representative, and which are based on many assumptions which may not hold true. WHO BoD data exist for the years 2002 and 2004, and a current round of updating these estimates is now in progress with new data expected towards the end of 2010 or early 2011 (Personal communication, D Bradshaw, August 2010). Arguably, South African national data which are derived from relatively well-developed vital registry data with verification at provincial and municipal level (at least for the Western Cape Province and the City of Cape Town) might be used, under explicit assumptions, to estimate comparative risks for indicator burden of disease components for other SADC countries and for modelling the effects of climate change and health in these countries.

Health systems

SADC countries' total expenditure on health as a percentage of gross domestic product (GDP) (2006) range from 2.6 to 12.9% (WHO 2009). The SADC region faces a major crisis in terms of human resources for health (Fig. 4). There is a critical shortage of health care workers compounded with maldistribution between and within countries as well as between the public and private sectors. It is estimated that the health workforce needs to be increased by about 140% to achieve enough coverage for essential health interventions (Anyangwe 2007). In South Africa, education and training of new doctors and nurses is not meeting the demand for health care workers (Lehmann 2008). Furthermore, progress with the development of mid-level cadres has been slow and the implementation of community health worker programmes has been fragmented and uneven. Health workers in services often find themselves poorly supported and resourced (Lehmann 2008).

Figure 4: Density of health workers in Africa compared to other regions



Climate change in the SADC region

Evidence shows that the SADC region is experiencing increasing frequency of hot days[1] and decreasing frequency of extremely cold days[2] (IPCC, UNDP Climate Change Country Profiles http://country-profiles.geog.ox.ac.uk). Rainfall trends are variable but evidence points to an increased inter-annual variability, with extremely wet periods and more intense droughts in different countries. Projections show that changes will not be uniform over the region (Fig. 5). The central southern land mass extending over Botswana, parts of north western South Africa, Namibia and Zimbabwe are likely to experience the greatest warming of 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 El Niño/La Niña-Southern Oscillation (ENSO)[3] patterns. Frequency of extremely dry winters & springs will increase to roughly 20%, while the frequency of extremely wet summers will double. Warming is predicted to increase the frequency and intensity of tropical storms in the Indian Ocean (INGC 2009, IPCC).

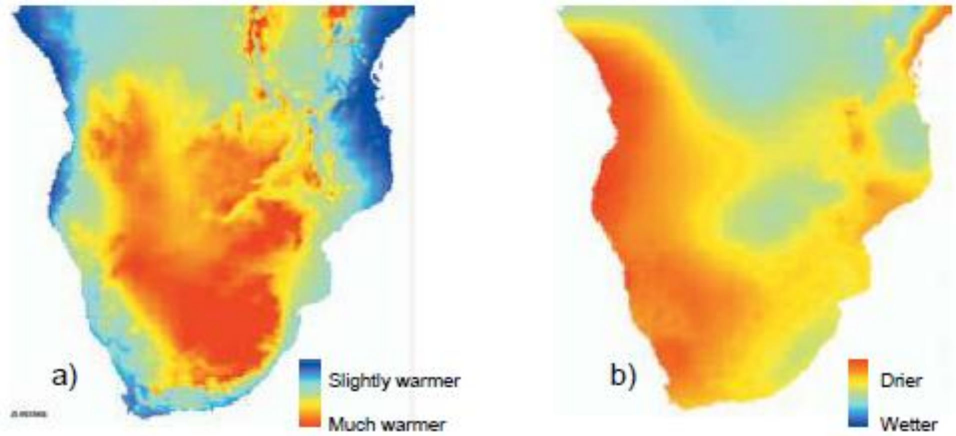


Figure 5: Projected climate change in southern Africa: HADCM3 climate model projections of changes in a) temperature and b) precipitation for 2050 relative to mean conditions over the 1961 to 1990 period, under the IPCC SRES A2 (high emissions) scenario (Scholes and Biggs, 2004).

---

[1] The temperature threshold for a 'hot day' in any region or season is defined by the daily maximum temperature which is exceeded on the 10% warmest of days in the standard climate period (1970-99). The index is then defined as the frequency with which daily maximum temperature exceeds this threshold in any month, season or year (UNDP CC Country Profiles http://country-profiles.geog.ox.ac.uk)

[2] The temperature threshold for a 'cold day' in any region or season is defined by the daily maximum temperature below which the 10% coldest days in the standard climate period (1970-99) fall. The index is defined as the frequency with which daily maximum temperature falls below this threshold in any month, season or year (UNDP CC Country Profiles http://country-profiles.geog.ox.ac.uk)

[3] ENSO, is a quasi-periodic climate pattern that occurs across the tropical Pacific Ocean on average every five years, but over a period which varies from three to seven years. It is characterised by variations in the temperature of the surface of the tropical eastern Pacific Ocean - warming or cooling known as *El Niño* and *La Niña* respectively - and air surface pressure in the tropical western Pacific - the *Southern Oscillation*. The two variations are coupled: the warm oceanic phase, El Niño, accompanies high air surface pressure in the west Pacific, while the cold phase, La Niña, accompanies low air surface pressure in the west Pacific.

Country-level climate data summaries have been prepared by the School of Geography and Environment, University of Oxford, with funding from the UNDP National Communication Support Programme (NSCP) and the UK government Department for International Development (DfID). Six of the SADC countries - Angola, Malawi, Mauritius, Mozambique, Tanzania and Zambia - were included in this summary. Details on recent and projected change in precipitation and climate are detailed in Appendices B and C. Mozambique is especially prone to the effects of rising sea levels (INGC 2009).

Most of the global GHG effect originates from industrialised or developed countries. Five African countries are responsible for most of Africa's GHG emissions and South Africa is by far the greatest emitter, responsible for 39% of the continental total - making GHG emissions in the SADC region relatively higher than those for other regions of Africa (http://www.eia.doe.gov/emeu/cabs/sadc.html) (Table 4).

SADC and Member Countries have elected to support international initiatives relevant to climate change such as the United Nations Framework Convention on Climate Change (UNFCCC), the Montreal Protocol, the Kyoto Protocol, the United Nations Convention on Biodiversity (CBD), and the United Nations Convention to Combat Desertification (CCD).

Table 4: Total energy and carbon dioxide emissions, 2003

http://www.eia.doe.gov/emeu/cabs/sadc.html

Country	Total Commercial Energy Consumption, (Quadrillion Btu)	Total Commercial Energy Production, (Quadrillion Btu)	Net Energy Exports, (Quadrillion Btu)	CO_2 Emissions (Million metric tons of carbon)
Angola	0.135	1.960	1.825	4.34
Botswana	0.052	0.023	-0.029	1.04
Comoros	0.001	0.000	-0.001	0.03
Democratic Republic of Congo	0.080	0.112	0.032	0.49
Lesotho	0.007	0.004	-0.003	0.06
Madagascar	0.037	0.006	-0.031	0.61
Malawi	0.025	0.013	-0.012	0.22
Mauritius	0.052	0.001	-0.051	1.01
Mozambique	0.166	0.157	-0.009	0.47
Namibia	0.051	0.015	-0.036	0.63
Seychelles	0.016	0.000	-0.016	0.32
South Africa	4.901	5.916	1.015	112.16
Swaziland	0.021	0.011	-0.010	0.37
Tanzania	0.078	0.032	-0.046	0.96
Zambia	0.108	0.090	-0.018	0.61
Zimbabwe	0.189	0.136	-0.053	3.01
Regional Total	*5.919*	*8.473*	*2.557*	*126.33*

SADC region, climate change and health

Despite the increasing international awareness and concern about the impact of climate change on health, and the consensus that the impact will vary by region with sub-Saharan Africa identified as being worst affected (Third Assessment Report of the IPCC), specific work linking climate change and health in Africa remains almost sparse and inconsistent (Byass 2009, McMichael 2009, Ramin 2009).

In 2010, an overview of health considerations in the National Adaptation Programmes of Action (NAPAs) for climate change in least-developed countries and small island states was conducted (Manga 2010). Within the context of the UNFCCC, these countries and small island states have been earmarked to receive specific support from developed countries to support their adaptation processes in relation to climate change. Since 2004, with support from the Global Environment Facility, the United Nations Environment Programme, the United Nations Development Programme and other organisations, NAPAs were developed to address the impacts of climate change. Manga (2010) reviewed a total of 41 NAPAs[4], including 29 from Africa and 12 from other least-developed countries and small island states. Thirty-nine of 41 NAPAs (95%) considered health as being one of the sectors on which climate change is seen as having an impact. However, only 23% (9/39) of the NAPAs were considered to be comprehensive in their health-vulnerability assessment (health-vulnerability assessment was considered to be comprehensive when a full range of potential health impacts was clearly specified).

In respect of coverage of health aspects, of the 39 NAPAs that include health in the vulnerability assessment, three do not specify any disease or medical condition. For the remaining 36 plans, the diseases most frequently listed are diarrhoeal disease (69%), malaria (59%), respiratory disease (25%) vector-borne disease other than malaria (19%) and malnutrition (19%). Other diseases and conditions mentioned include non-communicable diseases, parasitic diseases, meningitis, and ocular and skin diseases. Most adaptation activities were focused on biodiversity and agricultural activities with health not listed as a priority. In total, 73% (30/41) of the NAPAs included health interventions within adaptation needs and proposed actions, but only 27% (8/30) of these interventions were found to be adequate (interventions were considered adequate if they were perceived as being at least possibly effective as measures to respond to the identified climate impacts). The Democratic Republic of Congo, Lesotho, Malawi and Mozambique did not have health activities as part of their NAPAs. Only 11% (50 out of 459) of selected priority projects focused on health and only 3% of total NAPA budgets were allocated to health projects (Manga 2010).

The following section details the results of the search for existing studies on climate change and health in the SADC region.

---

[4] *Africa:* Benin, Burkina Faso, Burundi, Cape Verde, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Eritrea, Ethiopia, Gambia, Guinea, Guinea Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, Sao Tome & Principe, Senegal, Sierra Leone, Tanzania, Togo, Uganda and Zambia.
Other countries: Afghanistan, Bangladesh, Bhutan, Cambodia, Kiribati, Laos, Maldives, Samoa, Solomon Islands, Tuvalu, Vanuatu and Yemen.

4.2 CURRENT STATE OF KNOWLEDGE AND GAPS OF THE IMPACT OF CLIMATE CHANGE ON HEALTH IN SADC REGION

Considering the model of how climate change impact health and the various modulating factors, the SADC region is especially vulnerable to the impact of climate change due to poverty, high pre-existing disease burden, fragmented health services, water and food insecurity. The projected additional pressure of climate change on health systems is likely to influence the success of most countries to attain the health-related Millennium Development Goals (MDGs) related to eradication of extreme poverty and hunger, reduction of child mortality, improving maternal health and combating HIV and AIDS, malaria and other diseases http://www.undp.org/mdg/

4.2.1 Direct climate-related determinants of health

- Water and sanitation

Water resources are unevenly distributed in the region with community access to improved drinking-water sources ranging from 42% (Mozambique) to 100% (Mauritius) and to improved sanitation from 12% (Madagascar) to 94% (Mauritius) (2006 data as included in WHO 2009) (Table 5). The lack of universal access to clean water increases vulnerability to infectious diseases. It has been projected that almost all countries in the region are likely to experience significant reduction in stream flow (Dube 2009). Water-related health problems linked to water scarcity are predicted to worsen due to increased rainfall variability and high temperatures (Dube 2009).

Table 5: SADC region: access to improved drinking-water sources and sanitation

Country	Access to improved drinking-water sources (%)	Access to improved sanitation (%)
Angola	51	50
Botswana	96	47
DRC	46	31
Lesotho	78	36
Madagascar	47	12
Malawi	76	60
Mauritius	100	94
Mozambique	42	31
Namibia	93	35
Seychelles*	-	-
South Africa	93	59
Swaziland	60	50
Tanzania	55	33
Zambia	58	52
Zimbabwe	81	46

* Data not available

Because water is closely linked to food production, water-related problems will further compound malnutrition. Shortage of water may also lead to greater reliance on waste water recycling. Concerns are that some of the organic micro-pollutants are not removed by current wastewater treatment technology, and therefore an increased dependence on this water source has the potential to pollute ground and surface sources (Dube 2009).

The direct risks from rising sea levels include the physical hazards from current coastal inundation, more extensive episodes of flooding, and increasingly severe storms (especially at times of high tide). Damage to coastal infrastructure (roads, housing, and sanitation systems) would all pose direct risks to health (McMichael 2009). The Mozambique Initial National Communication Report 2003, identified the Beira coast to be the coastal area most vulnerable to sea level rise with indication from modelling results that erosion and floods will be a major problem by 2075 (Dube 2009). This will have major environmental and human health problems, for example, navigation channels will be affected by changes in water circulation and sediment distribution.

- Food security

A study by Kurukulasuriya and Mendelsohn found that even under positive scenarios, indications are that crop production in southern Africa will be adversely affected by climate change (Dube 2009). Impacts are likely to vary with soil types and types of crops grown (studies by Botswana Ministry of Works, Transport and Communications (2001) and Chipanshi (2003) included in Dube 2009). 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 affect further crop production in these regions and affect most subsistence farmers (studies by Dube 2003 and GECAFS (2006) included in Dube 2009).

Declining water supply will also negatively affect livestock production especially those subsistence farmers who rely heavily on surface water. Climate change will also affect livestock production through the change in the quantity, quality and cost of livestock feed. Furthermore, high temperatures and reduced water availability may directly affect the reproduction rates of cattle. For example, calving rates, milk production and general body weight (study by Easterling (2007) included in Dube 2009) may be affected by increased temperatures, with implication on protein availability in the region.

Marine life is predicted to be significantly affected. The increase of the temperature of the sea along the Mozambique Chanel 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 (Dube 2009).

- Extreme events

Extreme weather events and natural disasters are associated with significant mortality and morbidity. The impact in some of the SADC countries is detailed in Appendix D. There are indications that there is increased tropical cyclone activity in the Indian Ocean (Dube 2009, INGC 2009). 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:

- Death, injuries, destruction and loss of property leading to sudden change in community structures and family composition, with resultant psycho-social disorders.
- Increased susceptibility to infectious diseases due to population displacement, overcrowding, and shortage of water.
- Loss of tourism attractiveness and income resulting in increased poverty.
- Decline in food security and increased malnutrition resulting from contaminated coastal land that makes soil unsuitable for cultivation due to sea level rise

(Government of Seychelles 2000 in Dube 2009) and also disturbance of food distribution infrastructure.

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

4.2.2 Indirect climate-related determinants of health

Physical and energy infrastructure are fundamental to the capacity to cope with climate change, recover from several impacts and rebuild resilient communities. Frequent and severe floods and other extreme events damage infrastructure including buildings, roads, electricity systems and sanitation systems (Epstein 2008).

Rising sea levels also pose indirect risks to health. These include the salination of freshwater supplies – a particular problem for many small islands, as their aquifer 'cells' of water are encroached upon – the loss of productive farm land, and changes in breeding habitats for coastal-dwelling mosquitoes. Other indirect health risks include the mental health consequences of property loss, break-up of communities, displacement and emigration, and the possible risks of tension between displaced and receiving groups (McMichael 2009).
As a result of crop and pasture failure, many people in countries such as Botswana are abandoning crop production and moving either to cities or bigger settlements in search of economic opportunities. Urbanisation is associated with poorer housing conditions, unemployment, mental health conditions, exacerbation of chronic diseases, poor water and sanitation systems, and predisposes the population to rapid spread of disease especially during climate extremes such as floods. The SADC/ESD (2008) summarised the urban problem in the SADC region as follows: *"Rapid urbanization has led to urban sprawls 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".*

4.2.3 Important health outcomes for SADC region

Infectious diseases

Dube compared published articles on malaria, schistosomiasis, cholera, diarrhoeal diseases and meningitis, which refer to climate change (not necessarily climate-related studies) and found malaria articles to be most common (Table 6) (Dube 2009). Many 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 (Dube 2009).

Table 6. SADC region: Published articles on malaria, schistosomiasis, cholera, diarrhoeal diseases and meningitis which refer to climate change (Dube 2009)

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

Schistosomiasis

Study	Findings
Appleton 2008	Appleton 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.
Moodley 2003	Moodley, *et al.* used Geographical Information Systems (GIS) to produce temperature-suitability maps for schistosomiasis in South Africa where urinary and intestinal schistosomiasis occurs widely. As a result of limitations of the available disease data it was not possible to predict the prevalence of schistosomiasis in the identified climate-suitable areas.
Simoonga 2008	Simoonga 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 normalised difference vegetation index (NDVI) data.

Source: Dube 2009

Malaria

Study	Findings
Bodker 2003	In the highlands areas of Tanzania rainfall has been shown to increase the breeding sites of the *anopheline* mosquitoes.
Chirebvu 1999	Chirebvu *et. al.* (1999) 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 2004	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.
Hartmen 2002	Hartmen, *et al*. (2002) assessed climate suitability for stable malaria transmission in Zimbabwe under different scenarios and found much wider distribution of malaria transmission zones.
Korenromp 2004	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.
Pascual 2006	Malaria correlated with temperature changes in the highlands of Africa.
Small 2003	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.
Thomson 2005	Thomson, *et al.* (2005) showed strong links 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.
WHO 2003	Malaria epidemics in Zimbabwe have been found to be closely linked to climatic variability caused by events like El Niño (WHO 2003).
Yanda 2005	The 1997/1998 El Nino event was significantly associated with increased malaria epidemics in many areas of East Africa.

Source: Dube 2009, Epstein 2008, INGC 2009

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

Study	Findings
Boko 2007; Thomas 2004	By 2050 and continuing into 2080, some parts of southern-central Africa could become unsuitable for malaria transmission.
Hartmann 2002	Based on 16 climate change scenarios it is projected 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 2002; Ebi 2005	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.
Bok 2007; Hartmann 2002	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.

Source: Dube 2009

Diarrhoeal and cholera-related epidemics

Study	Findings
Birmingham 1997	Warming in the Great Rift Valley lakes may cause conditions that increase the risk of cholera transmission (Birmingham, *et al*., 1997).
Epstein 2008	Drought can also be associated with cholera and other water-borne diseases, due to the associated decline in personal hygiene and lack of adequate drinking water. The 1993 outbreak was associated with the 1992/93 El Niño-associated drought (Epstein, 2008).
Nchito 1998	*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	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.

Source: Dube 2009, INGC 2009

Meningococcal meningitis

Study	Findings
Boko 2007	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).
Desanker 2001	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.

Source: Dube 2009, INGC 2009

Tsetsefly - vectors of trypanosomes

Study	Findings
Roninson 2008	Collaborative work by Roninson, *et al*. (2008) involving scholars from 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 characterise 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.

Source: Dube 2009

Rodent-borne diseases

Study	Findings
Barreto 1995	Unstable weather conditions can lead to explosions of rodent populations. Heavy rainfall and flooding can lead to outbreaks of rodent-borne plague. On the other hand, in the Tete Province along the Malawian border, drought conditions have sometimes led to the movement of humans and rodents in search of food.

Source: Epstein 2008

HIV/AIDS

HIV/AIDS disproportionately impacts on women, increasing their vulnerability to climate-related health problems and, considering their central role in reproduction, family cohesion and economic activities, also the population as a whole. The spread of HIV/AIDS and other sexually transmitted infections is linked to a complex set of socio-economic factors including poverty and lack of social/family cohesion, resulting in migration and disruption of family structures. Climate change effects, especially extreme events, will lead to loss of livelihood and accelerate environmental refugees. Often people migrate to cities with the hope of finding employment, yet most end-up unemployed, with no proper housing, and food leading to survival strategies that make them vulnerable to contracting HIV. Reduced immunity from HIV will increase the risk of contracting malaria, diarrhoeal diseases and other opportunistic diseases that are also linked to poor living conditions (Drimie 2010).

Injuries

The MEDLINE search identified no studies on climate change and injuries in the SADC region.

Chronic diseases

The MEDLINE search identified no studies on climate change and chronic diseases in the SADC region.

Mental health

The MEDLINE search identified no studies on climate change and mental health in the SADC region.

Women's health

The MEDLINE search identified no studies on climate change and women's health in the SADC region.

Child health

The MEDLINE search identified no specific studies on climate change and child health in the SADC region.

Occupational health

Workers in heat-exposed jobs have reduced work capacity (Kjellstrom and Holmer 2009).

4.3 National, regional and international initiatives or institutions engaged in activities focused on climate change related to health in SADC

In order to provide a synthesis of national, regional and international initiatives or institutions engaged in activities focused on climate change related to health in the SADC region, a detailed list of key institutions and relevant stakeholders to contact were compiled.

The Centre for Health Research and Development Faculty of Life Sciences, University of Copenhagen, Denmark, reviewed health-related projects in Africa and found that, of the very few projects that had been conducted in Africa, more work was carried out in East Africa than in southern Africa (Dube 2009). As a result, extremely few institutions specialising in climate change and health were identified in the SADC region with the exception of South Africa which had a number of institutions working on non-health-related climate change. Most institutions work on cross-cutting issues of climate change with the majority of them focusing on adaptation. Furthermore, it was found that most of the work on climate change is being done through networks based in Europe and the US, funded by first world development agencies and academic grants (Dube 2009). A total of 36 networks were identified by Dube, *et al*. 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.

To avoid duplication, the list we developed was compared with organisations and institutions contacted by Dube 2009 and those institutions and stakeholders not included/covered by Dube (2009) were then contacted by email to request information (Appendix A). Of 30 email and/or telephonic enquiries, only five responses were received and of these only two (7%) seem to be related to climate change and health. We are following up with these organisations to obtain more detailed information.

5. DISCUSSION

This synthesis report was conducted on climate change and health in the Southern African Development Community (SADC) region in order to contribute to informed debate and the development of future climate change research, adaptation, surveillance and education programmes in the SADC region.

Evidence shows that the SADC region is experiencing increasing frequency of hot days and decreasing frequency of extremely cold days. Rainfall trends are variable but evidence points to an increased inter-annual variability, with extremely wet periods and more intense droughts in different countries. Projections show that changes will not be uniform over the region with the central, southern land mass extending over Botswana, parts of north western South Africa, Namibia and Zimbabwe being likely to experience the greatest warming of 0.2°C to 0.5°C per decade. Frequency of extremely dry winters and springs will increase to roughly 20%, while the frequency of extremely wet summers will double. Warming is also predicted to increase the frequency and intensity of tropical storms in the Indian Ocean.

The region is vulnerable to the impact of climate change due to poverty, high pre-existing disease burden, fragmented health services, and water and food insecurity. Despite the consensus that locally relevant information is necessary to inform policy and practice related to climate change, very few studies assessing the association between climate change and health in the SADC region have been conducted (Byass 2009, Dube 2009, Ramin 2009). Where research has been conducted, it focused on infectious diseases particularly malaria. Furthermore, an overview of health considerations in the National Adaptation Programmes of Action for climate change in least-developed countries and small island states found that health was not seen as a priority, as most activities focused on biodiversity and agricultural activities. Very few institutions specialising in climate change and health were identified in the SADC region.

Little work had been done on attributing disease burden to climate change. Assessing the burden of disease attributable to climate change is, however, a complex process as climate change is only one of several concurrent global environmental changes that simultaneously affect human health (McMichael 2010). Such assessments therefore need to take confounders and other modifying factors into consideration calling for integrated modelling.

Planning and action to address climate change and health need to be intersectoral, draw on local data and involve local and regional authorities and health care providers (Frumkin & McMichael, 2008). McMichael & Frumkin have completed significant work to formulate proposed strategies to assess and address the impact of climate change and health. The following section provides a summary of their work which is the ideal platform to start from to consider relevant actions for the SADC region.

6. FRAMEWORK OF PROPOSED ACTIONS TO CONSIDER FOR THE SADC REGION

The effects of climate change are not uniform and will vary by region and by population group. The impact on health will be influenced by local environmental conditions, socio-economic circumstances, the extent of adaptations implemented to minimise the full range of threats to health and other modulating factors (Frumkin 2008, McMichael 2009). The IPCC Working Group 2 report (2007) emphasises that the health impacts of CC will fall primarily on low-income, poorly-resourced and geographically vulnerable populations. Planning and action will thus need to be intersectoral, draw on local data and involve local and regional authorities and health care providers (Frumkin & McMichael, 2008). Frumkin recommends a public health approach to address the impacts of CC on health (Frumkin 2008).

Proposed actions can be grouped into mitigation, adaptation, education and training, and awareness raising. Research is central to these activities as it will inform approaches to use to assess the impact of strategies, compare various strategies, and inform best practices.

Mitigation

Five African countries are responsible for most of Africa's GHG emissions and South Africa, is by far the greatest emitter, responsible for 39% of the continental total - making GHG emissions in the SADC region relatively higher than those for other regions of Africa http://www.eia.doe.gov/emeu/cabs/sadc.html. Specific actions to enforce laws and regulations that protect health and ensure safety are therefore necessary components of the overall strategy to address climate change and health in the SADC region.

Adaptation

- Surveillance (Improved risk-indicator and disease surveillance specific to known climate change related risks and diseases).

- Disaster preparedness (INGC 2009)
    - Early-alert systems for impending weather extremes.
    - Disaster preparedness, and intersectoral capacity to deal with the aftermath.
- Better (climate-proofed) housing design (insulation, mosquitoes, etc.) and urban planning.
- Enhanced infectious disease control programmes (vaccines, vector control, case detection and treatment).
- Community-based neighbourhood support/watch schemes (e.g. for elderly, children).
- Mobilise community partnerships and actions to identify and solve health problems.
- Ongoing monitoring and evaluation of adaption strategies.

Education and training

- Incorporate climate change and health as part of undergraduate and post-graduate public health curricula.
- Develop training packages tailored to needs and scientific abilities (Lawrence 2008).
- Appropriate workforce training and mid-career development.
- Special efforts should be made to recruit trainees from areas at greatest risk from the health effects of climate change.

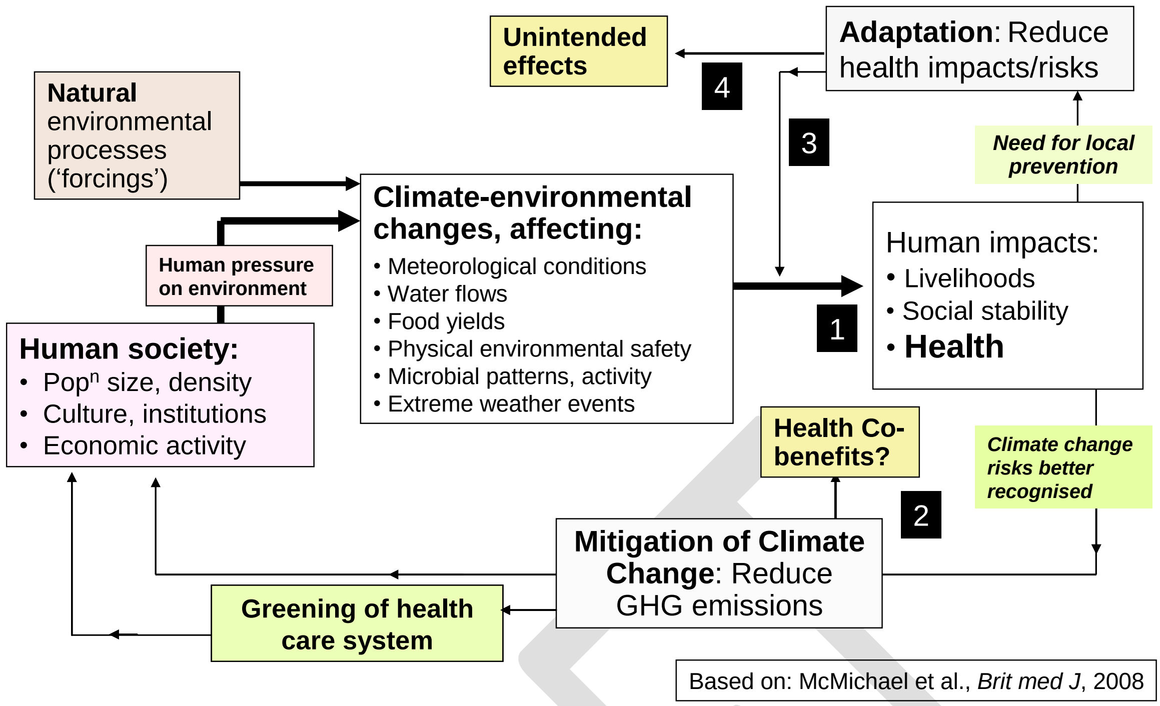
Awareness raising

Inform, educate and empower the public, policymakers and other stakeholders about health risks of climate change.

Research

The goal of research is to facilitate the reduction of both global and local health risks from climate change, via aetiological studies, risk assessments, integrated modelling of likely future health risks, evaluation of adaptive strategies (health gains and possible losses) and other strategies, and estimation of health-co-benefits (collateral localised health gains) from the actual mitigation actions (McMichael 2010). In the SADC region, specifically, more complete information is needed to enhance the detection and attribution of any ongoing impacts of climate change, and to estimate the health risks from projected future changes in climate.

- Epidemiological studies are needed to identify climate-health relationships, to quantify them and to identify high-risk groups/communities (McMichael 2010). McMichael (2010) identified a basic set of seven discrete research tasks which include (diagram):
  1a - Clarify relationships between (background) climate variation and health outcomes.
  1b - Estimate, statistically, current burden of disease attributable to climate change.
  1c - Seek evidence of actual current health impacts.
  2a - Develop scenario-based modelling to project future risk (including handling complexity & uncertainty).
  2b - Estimate health co-benefits of actions to avert/reduce further environmental change.
  3 - Evaluate health-protecting ('adaptive') actions.
  4 - Monitor for unintended consequences of adaptation.



Research task	Proposed epidemiological studies for SADC region
Clarify relationships between background climate variation and health outcomes	Incidence of heat-related illness in outdoor workers in plantation agriculture (Kjellstrom, Gabrysch, *et al.* 2009, Schulte 2009). Effect of background climate variation on food security and health (e.g. malnutrition and diarrhoeal disease in under 5s) using existing secondary or primary meteorological, agronomic data and health data.
Estimate, statistically, current burden of disease attributable to climate change	Using available secondary data (SADC burden of disease data exist and are currently being updated) to perform a comparative risk assessment of the burden of disease from climate change (Campbell-Lendrum and Woodruff 2006, Lewin 2007, Norman 2007).
Seek evidence of actual current health impacts	Perform a study of deaths for diarrhoea in under 5s in relation to the change in climate (e.g. drying). Similarly, examine the incidence of heat-related illness in outdoor workers in plantation agriculture in relation to extreme heat events as measured by the Wet Bulb Globe Temperature (WBGT) (Kjellstrom, Gabrysch, *et al.* 2009, Schulte 2009).
Develop scenario-based modelling to project future risk (including handling complexity & uncertainty)	Using estimates of risk obtained from ecological and from more detailed epidemiological studies to model the impacts of various climate change scenarios over time. Consider the roles of different predictors of the health outcome in complex regression models taking into account mediated and direct effects (Victora 1997). Predictors include the ability of the health system to detect and respond to increase adverse health outcomes.
Estimate health co-benefits of actions to avert/reduce further environmental change	Planting drought-resistant crop strains may have beneficial effects through a reduced need for agrichemicals.
Evaluate health-protecting ('adaptive') actions	Evaluate the impact of introducing a drought-resistant staple crop on rural malnutrition and a child health outcome.
Monitor for unintended consequences of adaptation	Study the impacts of a new drought resistant strain of staple crop on whether more chemical hazards to agricultural workers and residents emerge, or whether unintended adverse nutritional effects ensue, or whether the new strain may displace existing staples with negative overall nutritional impacts.

- Methodological research
  - In developing scenario-based modelling, it is important to incorporate confounding or interacting, non-climate variables. Integrated assessment modelling (or 'IAM') – would incorporate into the modelling information about: (i) ongoing trends in other determinants of health outcomes for which future extrapolations are considered feasible (e.g. demographic trends in age structures); (ii) likely future contextual conditions (e.g. uptake of domestic air-conditioning by 2050); (iii) advent of relevant vaccines and likely consequent population immunity level, and (iv) deliberate 'adaptive' changes (e.g. mosquito control programmes, heat wave warning systems, flood protection measures).

- Assessing the health effects of existing adaptation strategies.

- Assessing the health effects of mitigation strategies.

- Understanding the specific contribution of the health sector to global environmental change:
  - Assessment of the environmental effect of health sector resource use and waste generation.
  - Development of health sector practices which are sustainable in terms of resource use and waste generation.

- Estimate the economic costs of health impacts:
  - Prevention costs – associated with actions undertaken to maintain the current level of protection. Prevention costs would also include the cost of increasing adaptive capacity, which involves training, infrastructure costs, etc.
  - Treatment costs - These are the direct costs of treating a health outcome, such as treating infection.
  - Direct impact costs - These include the loss of life, loss of quality of life, and loss of earning capacity.

- Communication research:
  - Assessment of public and policymaker knowledge, attitudes and behaviours with respect to climate change and health (Frumkin& McMichael 2008).
  - Testing various communication strategies regarding climate change and health.

- Research related to education and training:
  - Assessment of training modalities and determining best education strategies to implement, e.g. face-to-face compared to e-learning.

"There is need for good, critical, thinking and research within each particular population setting, as to what are likely to be the 'early' and most reasonably attributable health impacts of climate change."

McMichael 2010

7. CONCLUSIONS

No substantial studies assessing the association between climate change and health in the SADC region have been conducted. Comprehensive planning and action to address climate change in the region need to be inter-sectoral, draw on local data and involve local and regional authorities and health care providers. There is a need for clear prioritised actions to assess the burden of disease attributable to climate change in the SADC region, to identify relevant adaptations for which there is existing evidence of effectiveness and cost efficiency in any part of the world, and particularly parts of the globe with similar CC scenarios, and to assess additional appropriate adaptation strategies.

8. REFERENCES

Anyangwe SCE, Mtonga C. Inequities in the Global Health Workforce: The Greatest Impediment to Health in Sub-Saharan Africa. *International Journal of Environmental Research and Public Health* 2007; **4**(2): 93-100.

Balbus JM, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. *J Occup Environ Med* 2009 Jan;51 (1):33-7.

Berry HL, Bowen K, Kjellstrom T. Climate change and mental health: a causal pathways framework. *Int J Public Health.* 2010 Apr;**55** (2):123-32. Epub 2009 Dec 22.

Bradshaw D, Norman R, Lewin S, Joubert J, Schneider M, Nannan N, *et al*. South African Comparative Risk Assessment Collaborating Group. Strengthening public health in South Africa: building a stronger evidence base for improving the health of the nation. *S Afr Med J* 2007; **97**: 643-9.

Bradshaw D, Norman R, Pieterse D, Levitt NS and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to diabetes in South Africa in 2000. *S Afr Med J* 2007; **97**: 700-6.

Byass P. Climate change and population health in Africa: where are the scientists? Global Health Action 2009: DOI: 10.3402/gha.v2i0.2065.

Campbell-Lendrum D, Corvalan C, Neira M. Global climate change: implications for international public health policy. *Bull WHO*, 2007; **85**: 235-7.

Campbell-Lendrum D, Woodruff R. Comparative risk assessment of the burden of disease from climate change. *Environmental Health Perspectives* 2006; **114** (12):1935-41.

Costello A, Abbas M, Allen A, *et al.* (The Lancet and University College London Institute for Global Health Commission). Managing the health effects of climate change. *Lancet* 2009; **373:** 1693-733.

Drimie S, Gillespie S. Review. Adaptation to climate change in Southern Africa: factoring in AIDS. *Environmental Science and Policy* 2010: doi:10.1016/j.envsci.2010.07.003

Dube OP, Chimbari MJ, on behalf of DBL – Centre for Health Research and Development Faculty of Life Sciences, University of Copenhagen, Denmark. Documentation of Research on Climate Change and Human Health in Southern Africa. July 2009.

Ebi K, Balbus J, Kinney PL, Lipp E, Mills D, O'Neill MS, et al. Chapter 2. Effects of global change on human health. Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems. 2008 Environmental protection agency.

Epstein P, Chu P, Cardoso AP, Nhassico D, Muquingue H, Cliff J. Mozambique: Climate change adaptation assessment for the INGC Health sector assessment, 2008.

Frumkin H, McMichael AJ. Climate change and public health: thinking, communicating, acting. *American Journal of Preventive Medicine* 2008; **35** (5): 403-10. doi:10.1016/j.amepre.2008.08.019

Frumkin H, Hess J, Luber G, Malilay J, McGeehin M. Climate change: the public health response. *Am J Public Health* 2008; **98:** 435-45.

Gage KL, Burkot TR, Eisen RJ, Hayes EB. Climate and vector-borne diseases. *American Journal of Preventive Medicine* 2008;**35** (5):436–50.

Groenewald P, Vos T, Norman R, et al. and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to smoking in South Africa in 2000. *S Afr Med J* 2007; 97: 674-81.

Hess JJ, Heilpern KL, Davis TE, Frumkin H. Climate Change and Emergency Medicine: Impacts and Opportunities. *Academic emergency medicine* 2009;**16:** 782–94.

Hess JJ, Malilay JN, Parkinson AJ. Climate Change. The Importance of Place. *American Journal of Preventive Medicine* 2008;**35** (5):468–78.

INGC. 2009. Synthesis report. INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [van Logchem B and Brito R (ed.)]. INGC, Mozambique.

IPCC (Solomon S, Qin D, Manning M, *et al.,* eds). *Climate Change 2007. The Physical Science Basis.* Contribution of Working Gp 1 to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press, 2007.
http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/

IPCC, 2007: *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A, eds.]. IPCC, Geneva, Switzerland, 104 pp.

IPCC (Parry M, Canziani O, Palutokof J, *et al.,* eds). *Impacts, Adaptation and Vulnerability.* Contribution of Working Gp 2 to Fourth Assessment Report of IPCC. Cambridge: Cambridge University Press, 2007 (Health = ch. 8). http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/

Johnson L, Bradshaw D, Dorrington R and the South African Comparative Risk Assessment Collaborating Group. The burden of disease attributable to sexually transmitted infections in South Africa. *S Afr Med J* 2007; **97:** 658-62.

Joubert J, Norman R, Bradshaw D, Goedecke JH, Steyn N, Puoane T and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to excess body weight in South Africa in 2000. *S Afr Med J* 2007; **97**: 683-90.

Keim ME. Building Human Resilience. The Role of Public Health Preparedness and Response as an Adaptation to Climate Change. *American Journal of Preventive Medicine* 2008;**35** (5):508–16.

Kistin EJ, Fogarty J, Pokrasso RS, McCally M, McCornick PG. Climate change, water resources and child health. *Arch Dis Child*. 2010;**95** (7):545-9.

Kjellstrom T, Kovats RS, Lloyd SJ, Holt T, Tol RS. The direct impact of climate change on regional labor productivity *Arch Environ Occup Health* 2009;**64** (4):217-27.

Kjellstrom T, Holmer I, Lemke B. Workplace heat stress, health and productivity - an increasing challenge for low and middle-income countries during climate change. *Global Health Action* 2009 Nov 11;2. doi: 10.3402/gha.v2i0.2047.

Kjellstrom T, Gabrysch S, Lemke B, Dear K. The “Hothaps” programme for assessing climate change impacts on occupational health and productivity: an invitation to carry out field studies. *Global Health Action* 2009; 11(2):DOI: 10.3402/gha.v2i0.2082

Kjellstrom T, Butler AJ, Lucas RM, Bonita R. Public health impact of global heating due to climate change: potential effects on chronic non-communicable diseases *Int J Public Health* 2009; DOI 10.1007/s00038-009-0090-2

Lawrence RS, Saundry PD. Climate Change, Health Sciences, and Education. *American Journal of Preventive Medicine* 2008;**35** (5):426-8.

Lehmann U**. (**2008.) Strengthening human resources for primary health care. In: Barron P and Roma-Reardon J (eds.) *South African Health Review* 2008. Chapter 11. Durban: Health Systems Trust.

Lewin S, Norman R, Nannan N, Thomas E, Bradshaw D and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to unsafe water and lack of sanitation and hygiene in South Africa in 2000. *S Afr Med J* 2007; **97**: 755-62.

Luber G, McGeehin M. Climate Change and Extreme Heat Events. *American Journal of Preventive Medicine* 2008;**35** (5):429–35.

Manga L, Bagayoko M, Meredith T, Neira M. Overview of health considerations within National Adaptation Programmes of Action for climate change in least developed countries and small island states. Geneva: WHO 2010.

Mash RJ, De Vries E, Abdul I. Diabetes in Africa: the new pandemic. Report on the 19th World Diabetes Congress, Cape Town, December 2006. *SA Fam Pract* 2007:**49**(6):44-50

McMichael AJ, Woodruff R, Hales S. Climate change and human health: present and future risks. *Lancet* 2006; **367**: 859-69.

McMichael AJ. Environmental change, climate and population health: a challenge for inter-disciplinary research. *Environ Health Prev Med* 2008; **13:** 183-6. DOI 10.1007/s12199-008-0031-3.

McMichael AJ. Climate change and human health. Chapter 1. *Commonwealth Health Minister’s Update.* 2009. 12-21

McMichael AJ. Climate Change, Global Environmental Change, and Health. Context, Concepts and Research Tasks for Epidemiologists. European Educational programme in Epidemiology. 2010.

McMichael AJ, Campbell-Lendrum DH, Corvalán CF, Ebi KL, GithekoAK, Scheraga JD, *et al.* Climate change and human health: risks and responses. World Health Organisation, 2003.

Nojilana B, Norman R, Dhansay A, Labadarios D, Van Stuijvenberg ME, Bradshaw D and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to iron deficiency anaemia in South Africa in 2000. *S Afr Med J* 2007; **97:** 741-6.

Norman R, Bradshaw D, Schneider M, Joubert J, Groenewald P, Lewin S, *et al.* A comparative risk assessment for South Africa in 2000: towards promoting health and preventing disease. *South African Medical Journal* 2007;**97** (8):637-41.

Nannan N, Norman R, Hendricks M, Dhansay MA, Bradshaw D and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease at*tributable to maternal and childhood undernutrition in South Africa in 2000. S Afr Med J* 2007; **97**: 733-9.

Norman R, Bradshaw D, Steyn K, Gaziano T and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to high cholesterol in South Africa in 2000. *S Afr Med J* 2007; **97**: 708-15.

Norman R, Cairncross E, Witi J, Bradshaw D and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to urban outdoor air pollution in South Africa in 2000. *S Afr Med J* 2007; **97**: 782-90.

Norman R, Mathee A, Barnes B, Van der Merwe L, Bradshaw D and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to lead exposure in South Africa in 2000. *S Afr Med J* 2007; **97**: 773-80.

Norman R, Barnes B, Mathee A, Bradshaw D and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to indoor air pollution in South Africa in 2000. *S Afr Med J* 2007; **97:** 764-71.

Norman R, Gaziano T, Laubscher R, Steyn K, Bradshaw D and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to high blood pressure in South Africa in 2000. *S Afr Med J* 2007; **97:** 692-8.

Patz JA, Vavrus SJ, Uejio CK, McLellan SL. Climate Change and Waterborne Disease Risk in the Great Lakes Region of the U.S. *American Journal of Preventive Medicine* 2008; **35**(5): 451–8.

Ramin BM, McMichael AJ. Climate Change and Health in Sub-Saharan Africa: A Case-Based Perspective. *EcoHealth*. 2009. DOI: 10.1007/s10393-009-0222-4.

SADC international conference on poverty & development. The impact of climate change SADC on the poverty situation in the region. "Regional Economic Integration: A Strategy for Poverty Eradication Towards Sustainable Development". 18 – 20 April 2008, Pailles, Mauritius.

Scholes RJ, Biggs R. Ecosystem Services in Southern Africa: a regional assessment. 2004. Council for Scientific and Industrial Research, Pretoria, 2004.

Schneider M, Norman R, Parry C, Plüddemann A, Bradshaw D and the South African Comparative Risk Assessment Collaborating Group. Estimating the burden of disease attributable to alcohol in South Africa in 2000. *S Afr Med J* 2007; **97**: 664-672.

Schulte PA, Chun H. Climate Change and Occupational Safety and Health: Establishing a Preliminary Framework. *Journal of Occupational and Environmental Hygiene* 2009;**6** (9):542-54.

Shea KM, American Academy of Pediatrics Committee on Environmental Health. Global climate change and children's health. *Pediatrics.* 2007;**120** (5):e1359-67. Epub 2007 Oct 29.

St. Louis ME, Hess JJ. Climate Change. Impacts on and Implications for Global Health *American Journal of Preventive Medicine* 2008;**35** (5):527–38.

Tawatsupa B, Lim LLY, Kjellstrom T, Seubsman S, Sleigh A and the Thai Cohort Study Team. The association between overall health, psychological distress, and occupational heat stress among a large national cohort of 40,913 Thai workers. *Global Health Action* 2010, **3**: 5034 - DOI: 10.3402/gha.v3i0.5034.

UNDP Climate Change Country Profiles http://country-profiles.geog.ox.ac.uk

Victora CG, Huttly SR, Fuchs SC, Olinto MT. The role of conceptual frameworks in epidemiological analysis: a hierarchical approach. *Intl J Epidemiol* 1997;**26** (1): 224-7.

Western Cape Burden of Disease Reduction Study. Abbreviated Report- "Popular Version" 2008 http://web.uct.ac.za/depts/oehru/publications/policy2.php (accessed August 2010).

Western Cape Burden of Disease Reduction Study Report Volume 2 Mortality Surveillance and Estimating the Burden of Disease 2007 http://web.uct.ac.za/depts/oehru/publications/policy2.php (accessed August 2010).

Western Cape Burden of Disease Reduction Study Report Volume 3 Major Infectious Diseases - HIV/AIDS and TB 2007 http://web.uct.ac.za/depts/oehru/publications/policy2.php (accessed August 2010).

Western Cape Burden of Disease Reduction Study Report Volume 4 Mental Health Disorders 2007 http://web.uct.ac.za/depts/oehru/publications/policy2.php (accessed August 2010).

Western Cape Burden of Disease Reduction Study Report Volume 5 Injury due to interpersonal violence and traffic 2007 http://web.uct.ac.za/depts/oehru/publications/policy2.php (accessed August 2010).

Western Cape Burden of Disease Reduction Study Report Volume 6 Cardiovascular Diseases 2007 http://web.uct.ac.za/depts/oehru/publications/policy2.php (accessed August 2010).

Western Cape Burden of Disease Reduction Study Report Volume 7 Childhood Diseases Overview 2007 http://web.uct.ac.za/depts/oehru/publications/policy2.php (accessed August 2010).

WHO. *Gender, climate change and health*. Geneva: WHO, 2005.

WHO. *World Health Statistics 2009*. Geneva: WHO, 2009.

9. APPENDICES

Appendix A. Organizations/institutions contacted for information on activities related to climate change and health in the SADC region.

Initiatives contacted in SADC countries				
Name	**Position / org**	**Contact details**	**Activities in CC & health**	**Status**
	WHO AFRO via NEPAD Advisor on Public Health and via WHO Geneva			James to contact
Prof Imelda Bates	Liverpool School of Tropical Medicine			James to contact
Dr Jim Creighton	CDC Lesotho (CDC former Regional Director)			James to contact
Richard Feacham originator of Global Fund	Univ of California (UCSF) Institute of Global Health			James to contact
	Ethiopian Working Group on Climate Change	pheethiopia@gmail.com www.phe-ethiopia.org		E-mail sent MG
Mr Paghe	Botswana's Committee on Climate Change (BCCC-which has Health represented on the Committee)			James to contact
Kay Montgomery	CAP Climate Action Partnership /Wits Unit working on CC			James to contact
	Africa Centre-Malaria Demographic Surveillance System (UKZN)			James to contact
Prof Steve Tollman	Wits Rural Health Facility			James to contact
Prof Barry Schoub	National Institute of Communicable Diseases (NICD)			James to contact
	Danish Development Research Network	Department of Geography and Geology		E-mail sent MG

	DDRN	University of Copenhagen Øster Voldgade 10 1350 Copenhagen K Phone: +4535324187 **www.ddrn.dk** **info@ddrn.dk**		
Chimbari	Southern African Climate Change Network	University of Botswana mjchimbari@gmail.com maf@ddrn.dk		E-mail sent MG
Julie Cliff	National Institute of Disaster Management, Mozambique	INGC MAIN OFFICE, RUA DA RESISTÊNCIA 1746, 8TH FLOOR TEL. 416007/8 FAX. 417576/417575 DOP-TEL. 414075/6/7/8 FAX. 414074, 10TH FLOOR http://www.ingc.gov.mz/ ingc@teledata.mz		E-mail sent MG, tried to call a number of times
Nelson Sewankambo	Director, African Initiative	The Centre for International Governance Innovation 57 Erb Street West, Waterloo, Ontario Canada N2L 6C2 tel +1.519.885.2444 fax +1.519.885.5450 www.cigionline.org nsewankambo@cigionline.org		Email sent MG

		eDybenko@cigionline.org		
	PHASA and schools of Public Health in the SADC region			Contacted by MG
Dr Ronnie Bock	*Biodiversity/Environment*	UNAM Dept of Biological Sciences P/Bag 13301 Windhoek Namibia Phone: 061 2063423 Fax: 2063791 rbock@unam.na	Works in Malaria only with Namibian Ministry of Health. Looking at monitoring vectors and parasites, vector control issues, spread/epidemiology of malaria in country, including impact of changes in rainfall patterns and drought	
Peter Erb	*Local coordinator Namibia Member of: Local Coordination Namibia*	Windhoek Namibia Phone: +264 61 377 500 (temporarily until end of June) p.erb@rssc-southernafrica.net		Email sent MG
Dr Joh Henschel	*Executive Director Gobabeb Centre Wildlife and Tourism*	Box 953 Windhoek/bay Namibia Phone: 064 694198 (Wbay) Fax: 064 694197 Cellphone: 081 277 1715 jhenschel@drfn.org.na		Email sent MG
Ms Maria Amakali	*Water* MAWF	DWA P/Bag 13184 Windhoek Namibia Phone: 2087212 Fax: 2087227 amakalim@mawrd.gov.na		Email sent MG, phone just rings
Dr Graham Hopwood	*Director Capacity Development*	Institute for Public Policy Research (IPPR) Namibia Cellphone: 61240		Email sent MG

		514 director@ippr.org.na		
Jonathan Diederiks	*Local coordinator South Africa* *Member of: Local Coordination South Africa* *National Co-ordinator: Regional Science Service Centre/NRF*	South Africa jostian@gmail.com jonathan.diederiks@nrf.ac.za	Working on climate change and land management	
Robert Kriger	National Research Foundation NRF	International Research and Cooperation (IR&C) Meiring Naude Road, Brummeria, PO Box 2600 0001 Pretoria South Africa +27 12 481 4141 rskriger@nrf.ac.za		Email sent MG, phone messages left
Prof. Dr. Guy Brasseur	*Head of the Institution* *Director*	Climate Service Center (CSC) Bundesstr. 45 20146 Hamburg Germany Phone: ++49 40 226 338 402 Fax: ++49 40 226 338 163 guy.brasseur@gkss.de		Email sent MG
Beaton S. Kaluba	*Chief Science and Technology Officer* *Member of: Interim Committee, Focal Point Zambia*	Ministry of Science Technology and Vocational Training Department of Science and Technology Maxwell House, Los Angeles Boulevard, P. O. Box 50464 Lusaka Zambia Phone: ++260		Email sent MG

		211 252092 Fax: ++260 976 958716, ++290 966 880488 bskaluba@mstvt.gov.zm		
Mr John L. Chongo	*Senior Science and Technology Officer* *Member of: Focal Point Zambia*	Ministry of Science Technology and Vocational Training Department of Science and Technology Zambia Phone: ++260 977 884705 jlchongo@mstvt.gov.zm	Working in research and development activities on climate change – couldn't ascertain whether health included	
Dr Gabriel Luís Miguel	*Doutor em Ciências Ambientais* *Member of: Focal Point Angola*	Ministry of Research (MESCT) Luanda Angola gabrielmig@gmail.com		Email sent MG He responded to say he had passed it on to colleagues but I received nothing further.
Oabona C. Monngakgotla	*Member of: Focal Point Botswana*	Department of Research, Science and Technology Ministry of Communications, Science and Technology Gaborone Botswana omonngakgotla@gov.bw		Email sent MG
	Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN)	accid@fanrpan.org http://www.fanrpan.org	They do policy and advocacy work including climate change. They have 2 climate change projects which would include some health aspects – one on strategies for adapting to climate change in rural sub-Saharan Africa which includes 14 countries (including all the SADC countries, excluding the	

			Seychelles) and involves a review of their national plans; and, one on building climate change resilience in agricultural programmes which is mostly focused on East Africa	
COMESA		webmaster@comesa.int Zambia		Email sent MG
Dr Raj Naidoo	Department of Environmental Health, UKZN	031 260 4385	Currently doing a research project looking at data including health data from air pollution in S Durban area	

UNDP Climate Change Country Profiles http://country-profiles.geog.ox.ac.uk

Appendix B: Precipitation

Country	Recent Climate Trends				GCM Projections of Future Climate			
	Mean monthly precipitation	Indices of extreme daily precipitation			Mean monthly precipitation	Indices of extreme daily precipitation		
		% of total rainfall falling in 'heavy' events	Max 1-day rainfall	Max 5-day rainfall		% of total rainfall falling in 'heavy' events	Max 1-day rainfall	Max 5-day rainfall
Malawi	Observations of rainfall over Malawi do not show statistically significant trends. Wet-season rainfall over Malawi in 2006 was particularly low, causing an apparent decreasing trend in DJF rainfall but there is no evidence of consistent decreases.	There are no statistically significant trends in the extremes indices calculated using daily precipitation observations.			Projections of mean rainfall do not indicate substantial changes in annual rainfall. The range of projections from different models is large and straddles both negative and positive changes (-13% to +32%). Seasonally, the projections tend towards decreases in dry season rainfall and increases in wet season rainfall.	↑of up to 19% by the 2090s (esp. wet seasons)	↑ 1- and 5-day rainfall maxima by the 2090s under the higher emissions scenarios, of up to 26mm in 1-day events, and 39mm in 5-day events. These also generally increase in wet season, but decrease in dry season.	
Angola	Mean annual rainfall over Angola has decreased at an average rate of around 2mm per month (2.4%) per decade between 1960 and 2006. This annual decrease is largely due to decreases in MAM rainfall, which has decreased by 5.0mm per month (5.4%) per decade.	There is not sufficient daily precipitation data available to determine trends in the contribution of heavy rainfall events to total rainfall. Available 5-day maximum rainfall data indicate no discernable or significant trends.			Wide range of changes in precipitation. Projected change range from -27 to +20% by the 2090s, with ensemble median values of -1 to -6%. • Projected decreases in rainfall are largely for SON and JJA rainfall. Projections for these seasons are for changes of -65 to +42% in JJA and -43 to +26% in SON.	↑ in all seasons except for JJA, when decreases are indicated.	May increase in magnitude in DJF and MAM.	

Tanzania	Statistically significant ↓ trends in annual, and JJAS and MAM rainfall. Annual rainfall has decreased at an average rate of 2.8mm per month (3.3%) per decade. The greatest annual decreases have occurred in the southern most parts of Tanzania. MAM and JJAS rainfalls have decreased by 4.0 and 0.8 mm per month per decade, respectively (3.0% and 6.0%).	Trends in the extreme indices based on daily rainfall data are mixed. There is no statistically significant trend in the proportion of rainfall occurring in heavy events. 1- and 5-day rainfall maxima show small, non-statistically significant decreasing trends. 5-day events show a significant increasing trend of +11.03mm per decade in MAM.	Projections of mean rainfall are broadly consistent in indicating increases in annual rainfall. The ensemble range spans changes of -4 to +30% by the 2090s, and ensemble median changes of +7 to +14%. Rainfall generally increases in the wet-season(s) of each region.	↑ range from 1 to 14% in annual rainfall by the 2090s. Increases affect most of the country in the seasons JF, MAM and SON.	↑ by the 2090s of up to 24mm in 1-day events, and 4 to 37mm in 5-day events. The largest increases are seen in MAM.
Zambia	Mean annual rainfall over Zambia has decreased by an average rate of 1.9mm per month (2.3%) per decade since 1960. This annual decrease is largely due to decreases in DJF rainfall, which has decreased by 7.1mm per month (3.5%) per decade.	Daily precipitation observations show some indication of reductions in the contribution of heavy events to total rainfall, and the magnitude of maximum 1- and 5-day rainfalls, but none of these trends are statistically significant.	Projections of mean rainfall do not indicate large changes in annual rainfall. Seasonally, the range of projections from different models is large, but ensemble indicate decreases in SON rainfall (-39 to +14% by 2090) and increases in DJF rainfall (-11 to +15%), particularly in the north-east of the country.	↑ annually, but mainly in DJF and MAM.	Projections indicate that maximum 1- and 5-day rainfalls may increase in magnitude in DJF and MAM.
Mozambique	Mean annual rainfall over Mozambique has decreased at an average rate of 2.5mm per month (3.1%) per decade between 1960 and 2006. This annual decrease is largely due to decreases in DJF rainfall, which has decreased by 6.3mm per month (3.4%) per decade.	Daily precipitation observations indicate that despite observed decreases in total rainfall, the proportion of rainfall falling in heavy events has increased at an average rate of 2.6% and 5-day annual rainfall maxima have increased by 8.4 mm per decade, with largest increases in the wet season, DJF.	Projections of mean rainfall do not indicate substantial changes in annual rainfall. The range of projections from different models is large and straddles both negative and positive changes (-15 to +20mm per month, or -15% to +34%). Seasonally, the projections show a more	↑ of up to 15% by the 2090s. For DJF by up to 18%. Models are also broadly consistent in indicating increases in MAM, but decreases in	↑ maxima by the 2090s under the higher emissions scenarios of up to 20mm in 1-day events, and 34mm in 5-day events. These also generally increase in DJF and MAM, but decrease in JJA and SON.

			coherent picture, with the projections tending towards decreases in dry season rainfall, offset partially by increases in wet season rainfall.	JJA and SON. .	
Mauritius	The large inter-annual and inter-decadal variations in rainfall in this part of the world mean that it is difficult to identify long-term trends. Whilst there is no evident trend in annual rainfall, OND rainfall has declined over the period 1960 to 2006, at an average rate of 7.7mm per month (8.7%) per decade.	There are insufficient daily rainfall observations available to identify trends in daily rainfall extremes.	The range of projections in mean annual rainfall from different models is large and straddles both negative and positive changes (-20% to +24%), with ensemble median changes close to zero. Seasonally, the projections show a more coherent picture, with the projections for JAS rainfall tending towards decreases. Changes in this season range between -27 and +15% by the 2090s, with ensemble median values -6 to -10%. • Projected changes tend towards increases over the northern islands and decreases over the southern islands in all seasons.	The projections of change in the proportion of rainfall that falls in heavy events range between both increases and decreases. Seasonally, projections are more coherent in JAS, indicating decreases, with changes ranging between -13% to +5%.	The models are broadly consistent in indicating overall increases in 1- and 5-day rainfall maxima by the 2090s. The models indicate decreases in these values, however, in JAS.

UNDP Climate Change Country Profiles http://country-profiles.geog.ox.ac.uk

Appendix C: Temperature

Country	Recent Climate Trends					GCM Projections of Future Climate			
	Mean annual temp	Average number of 'hot' days/year	Average number of 'hot' nights/ year	Average number of 'cold' days / year	Average number of 'cold' nights/ year	Mean annual temp	Average number of hot days/year	Average number of 'hot' nights/ year	Average number of 'cold 'days and 'cold' nights/ year
Malawi	↑ by 0.9°C between 1960 and 2006, an average rate of 0.21°C per decade.	↑ by 30.5 (additional 8.3% of days[2]) between 1960 and 2003.	↑ by 41 (additional 11.1% of nights) between 1960 and 2003.	↓ by 16 (4.3% of days) between 1960 and 2003.	↓ by 33 (8.9% of days).	↑ by 1.1 to 3.0°C by the 2060s, and 1.5 to 5.0°C by the 2090s.	14-32% of days by the 2060s, and 15-53% of days by the 2090s.	27-53% of nights by the 2060s and 31-72% of nights by the 2090s.	↓ frequency. These events are expected to become exceedingly rare, and do not occur at all under the highest emissions scenario (A2) by the 2090s.
Angola	↑ by 1.5°C between 1960 and 2006, an average rate of 0.33°C per decade.	↑ by 49 (an additional 13.4% of days[2]) between 1960 and 2003.	↑ by 44 (an additional 12.0% of days) between 1960 and 2003.	↓by 23 (6.4% of days) between 1960 and 2003.	↓by 43 (11.8% of nights) between 1960 and 2003.	↑ by 1.2 to 3.2°C by the 2060s, and 1.7 to 5.1°C by the 2090s.	20-40% of days by the 2060s, and 25-65% of days by the 2090s.	29-59% of nights by the 2060s and 37-91% of nights by the 2090s.	↓ frequency. These events are expected to become exceedingly rare, occurring on maximum of 1-4% of days in the year, and potentially not at all by the 2090s in many of the projections.
Mozambique	↑ by 0.6°C since between 1960 and 2006, an average rate of 0.13°C per decade.	↑ by 25 (an additional 6.8% of days[2]) between 1960 and 2003.	↑ 31 (an additional 8.4% of nights) between 1960 and 2003.	↓ by 14 (3.9% of days) between 1960 and 2003.	↓ by 27 (7.4% of days).	↑ by 1.0 to 2.8°C by the 2060s, and 1.4 to 4.6°C by the 2090s.	17-35% of days by the 2060s, and 20-53% of days by the 2090s.	25-45% of nights by the 2060s and 29-69% of nights by the 2090s.	↓ frequency. These events are expected to become exceedingly rare, and do not occur at all under the highest emissions scenario (A2) by the 2090s.

1 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.

2 'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.

Country	Recent Climate Trends					GCM Projections of Future Climate			
	Mean annual temp	Average number of 'hot' days/year	Average number of 'hot' nights/ year	Average number of 'cold' days/year	Average number of 'cold' nights/ year	Mean annual temp	Average number of hot days/year	Average number of 'hot' nights/ year	Average number of 'cold 'days and 'cold' nights/ year
Tanzania	↑by 1.0°C since 1960, an average rate of 0.23°C per decade	Only ↑ in DJF by 2.5 days per month (an additional 8.2% of DJF days) between 1960 and 2003.	↑by 50 (an additional 13.6% of nights) between 1960 and 2003.	not changed	↓by 34 (9.3% of days).	↑by 1.0 to 2.7°C by the 2060s, and 1.5 to 4.5°C by the 2090s	19-40% of days by the 2060s, and 19-65% of days by the 2090s	30-68% of nights by the 2060s and 35-91% of nights by the 2090s.	↓ frequency. These events are expected to become exceedingly rare, with cold days occurring on 0-4% of days and cold nights occurring on a maximum of 1% of days, and not at all under the two higher emissions scenarios, by the 2090s.
Mauritius	↑ by 0.6°C since 1960, an average rate of 0.13°C per decade.	There is insufficient daily temperature data available from which to determine trends in daily temperature extremes.				↑ by 1.0 to 2.0°C by the 2060s, and 1.1 to 3.4°C by the 2090s.	29-48% of days by the 2060s, and 33-71% of days by the 2090s.	29-48% of nights by the 2060s and 32-71% of nights by the 2090s.	↓ frequency. 'Cold' days do not occur in any projection, under any emissions scenario by the 2090s, and cold nights only occur under the lowest emissions scenario by the 2090s.
Zambia	↑by 1.3°C since 1960, an average rate of 0.29°C per decade.	↑by 43 (an additional 11.8% of days2) between 1960 and 2003.	↑by 43 (an additional 11.6% of nights) between 1960 and 2003.	↓by 22 (6% of days) between 1960 and 2003.	↓by 35 (9.7% of days)	↑by 1.2 to 3.4°C by the 2060s, and 1.6 to 5.5°C by the 2090s	15-29% of days by the 2060s, and 16-49% of days by the 2090s.	26-54% of nights by the 2060 and 30-80% of nights by the 2090s	↓ frequency. These events are expected to become exceedingly rare, occurring on maximum of 1-4% of days in the year, and potentially not at all by the 2090s in many of the projections. Cold nights decrease in frequency more rapidly than cold days.

1 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.
2 'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.

Appendix D

Principle Extreme weather events and natural disasters affecting Malawi 1979-2009

		# of Events	Killed	Total Affected	Damage (000 US$)
Drought	**Drought**	6	500	19,678,702	-
	ave. per event		83.3	3,279,783.7	-
Earthquake (seismic activity)	**Earthquake** (ground shaking)	1	9	50,100	28000
	ave. per event		9	50,100	28000
Epidemic	**Unspecified type**	2	175	-	-
	ave. per event		87.5	-	-
	Bacterial Infectious Diseases	10	1,321	46,650	-
	ave. per event		132.1	4,665	-
Flood	**Unspecified flood**	9	22	386390	1000
	ave. per event		2.4	42932.2	111.1
	Flash flood	4	481	339,246	24000
	ave. per event		120.3	84,811.5	6000
	General flood	8	11	65,3599	89
	ave. per event		1.4	81,699.9	11.1
	Storm surge/coastal flood	2	67	518,500	6700
	ave. per event		33.5	259,250	3350
Storm	**Unspecified storm**	1	11	8	-
	ave. per event		11	8	-

Malawi Disaster Summary Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net UniversitÈ Catholique de Louvain - Brussels - Belgium" Created: May-28-2009. Data version: v12.07

Malawi disaster impacts

Affected populations of top 10 disasters			Mortality impacts of top 10 disasters		
Total population (2006) 13,571,000					
Disaster	**Date**	**Affected (no. of people)**	**Disaster**	**Date**	**Killed (no. of people)**
Drought	1992	7,000,000	Epidemic	2001	609
Drought	2005	5,100,000	Epidemic	2001	502
Drought	2002	2,829,435	Drought	2002	500
Drought	1990	2,800,000	Flood	1991	472
Drought	1987	1429267	Epidemic	2002	175
Drought	2007	520000	Epidemic	2000	83
Flood	2001	500000	Flood	2001	59
Flood	1997	400000	Epidemic	2002	41
Flood	2002	246340	Epidemic	1989	35
Flood	2007	180246	Epidemic	2001	20

Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net UniversitÈ Catholique de Louvain - Brussels - Belgium" Created: May-28-2009. Data version: v12.07

Impacts of extreme weather events and natural disasters in Mozambique 1979-2009

Event	Event type	# of Events	Killed	Total Affected	Damage (000 US$)
Drought	Drought	10	100068	11297500	50000
	ave. per event		10006.8	1129750	5000
Earthquake (seismic activity)	Earthquake (ground shaking)	1	4	1476	-
	ave. per event		4	1476	-
Epidemic	Unspecified	1	11	1810	-
	ave. per event		11	1810	-
	Bacterial infectious diseases	19	2727	315431	-
	ave. per event		143.5	16601.6	-
	Parasitic infectious diseases	1	-	16773	-
	ave. per event		-	16773	-
Flood	Unspecified	4	22	813535	100000
	ave. per event		5.5	203383.8	25000
	General flood	13	975	6225337	503100
	ave. per event		75	478872.1	38700
	Storm surge/coastal flood	2	83	649329	36000
	ave. per event		41.5	324664.5	18000
Insect infestation	Unspecified	1	-	-	-
	ave. per event		-	-	-
Mass movement wet	Landslide	1	87	2500	-
	ave. per event		87	2500	-
Storm	Unspecified	4	17	5117	-
	ave. per event		4.3	1279.3	-
	Tropical cyclone	10	508	3462097	110550
	ave. per event		50.8	346209.7	11055
	Unspecified	1	49	3023	-
	ave. per event		49	3023	-

Mozambique Disaster Summary
Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net Universit**È** Catholique de Louvain - Brussels - Belgium" Created: May-28-2009. Data version: v12.07

Mozambique disaster impacts 1981-2007

Affected populations of top 10 disasters			Mortality impacts of top 10 disasters		
Total population (2006) 20,971,000					
Disaster	**Date**	**Affected (no. of people)**	**Disaster**	**Date**	**Killed (no. of people)**
Drought	1981	4,750,000	Drought	1981	100,000
Flood	2000	4,500,000	Flood	2000	800
Drought	1991	3,300,000	Epidemic	1997	619
Storm	1994	2,502,000	Epidemic	1990	588
Drought	2005	1,400,000	Epidemic	1992	587
Drought	2002	600,000	Storm	1994	240
Flood	2001	549,326	Epidemic	1983	189
Drought	2007	520,000	Storm	1984	109
Flood	1981	500,000	Epidemic	1998	109
Flood	1985	500,000	Epidemic	1990	106

Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net UniversitÈ Catholique de Louvain - Brussels - Belgium" Created: May-28-2009. Data version: v12.07

Impacts of extreme weather events and natural disasters in Tanzania 1979-2009

Event	Type of Event	# of Events	Killed	Total Affected	Damage (000 US$)
Drought	Drought	6	-	7964000	-
	ave. per event		-	1327333.3	-
Earthquake (seismic activity)	Earthquake (ground shaking)	4	5	8491	-
	ave. per event		1.3	2122.8	-
	Tsunami	1	10	-	-
	ave. per event		10	-	-
Epidemic	Unspecified	4	245	1055	-
	ave. per event		61.3	263.8	-
	Bacterial Infectious Diseases	17	5200	82853	-
	ave. per event		305.9	4873.7	-
	Parasitic Infectious Diseases	1	590	4853	-
	ave. per event		590	4853	-
	Viral Infectious Diseases	4	126	978	-
	ave. per event		31.5	244.5	-
Flood	Unspecified	9	188	411308	3510
	ave. per event		20.9	45700.9	390
	Flash flood	3	66	4800	-
	ave. per event		22	1600	-
	General flood	12	301	232471	280
	ave. per event		25.1	19372.6	23.3
Insect infestation	Locust	1	-	-	-
	ave. per event		-	-	-
Mass movement wet	Landslide	1	13	150	-
	ave. per event		13	150	-
Storm	Local storm	2	-	677	-
	ave. per event		-	338.5	-
	Tropical cyclone	1	4	2500	-
	ave. per event		4	2500	-
Wildfire	Scrub/grassland fire	1	-	-	-
	ave. per event		-	-	-

Tanzania Disaster Summary

Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net UniversitÈ Catholique de Louvain - Brussels - Belgium" Created: May-28-2009. Data version: v12.07

Tanzania disaster impacts

Affected populations of top 10 disasters			Mortality impacts of top 10 disasters		
Total population (2006) 39,359,000					
Disaster	**Date**	**Affected (no. of people)**	**Disaster**	**Date**	**Killed (no. of people)**
Drought	1996	3000000	Epidemic	30/01/1997	2025
Drought	1984	1900000	Epidemic	1/1/98	1871
Drought	Aug-03	1900000	Epidemic	13/05/1998	590
Drought	1991	800000	Epidemic	Nov-77	500
Drought	Oct-04	254000	Epidemic	21/11/1997	304
Flood	12/2/93	201543	Epidemic	Dec-91	290
Flood	3/4/90	162000	Epidemic	1991	284
Flood	7/4/89	141056	Epidemic	Jan-90	200
Drought	1988	110000	Flood	3/4/90	183
Flood	Jun-79	90000	Epidemic	Apr-83	163

Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net UniversitÈ Catholique de Louvain - Brussels - Belgium" Created: May-28-2009. Data version: v12.07

Impacts of extreme weather events and natural disasters in Zambia 1979-2009

Event	Type of Event	# of Events	Killed	Total Affected	Damage (000 US$)
Drought	Drought	5	-	4173204	-
	ave. per event		-	834640.8	-
Epidemic	Unspecified	2	393	11450	-
	ave. per event		196.5	5725	-
	Bacterial infectious diseases	12	461	40362	-
	ave. per event		38.4	3363.5	-
	Viral infectious diseases	2	136	667	-
	ave. per event		68	333.5	-
Flood	Unspecified	2	5	1917900	20700
	ave. per event		2.5	958950	10350
	General flood	11	15	2591929	-
	ave. per event		1.4	235629.9	-
Insect infestation	Locust	1	-	-	-
	ave. per event		-	-	-

Zambia Disaster Summary

Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net Universit̀E Catholique de Louvain - Brussels - Belgium" Created: May-28-2009. Data version: v12.07

Affected populations of top 10 disasters

Total population (2006) 11,696,000

Disaster	Date	Affected (no. of people)
Drought	1991	1700000
Flood	10/1/07	1400000
Flood	6/2/98	1300000
Drought	Aug-95	1273204
Drought	Jun-05	1200000
Flood	23/01/1989	800000
Flood	Feb-01	617900
Flood	1/2/04	196398
Flood	20/01/2007	118755
Flood	30/12/2007	34776

Mortality impacts of top 10 disasters

Disaster	Date	Killed (no. of people)
Epidemic	1999	393
Epidemic	4/12/03	179
Epidemic	Jan-00	163
Epidemic	Dec-90	85
Epidemic	Jul-82	51
Epidemic	6/1/99	44
Epidemic	May-99	23
Epidemic	13/08/2005	21
Flood	Feb-78	11
Epidemic	Mar-01	11

- Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net UniversitÈ Catholique de Louvain - Brussels - Belgium" Created: May-28-2009. Data version: v12.07