Save the Children UK:
Southern Africa scenario planning paper

A PRELIMINARY ASSESSMENT OF ENVIRONMENTAL VULNERABILITY IN SOUTHERN AFRICA

Coleen Vogel
University of the Witwatersrand

017chv@cosmos.wits.ac.za

SARPN acknowledges permission from ESC UK for permission to post this document on our website

October 2002

TABLE OF CONTENTS

TERMS OF REFERENCE

The following report is an analysis of some of the current and potential environmental factors that are and may affect children in the SADC region.[1] The report has been written within the following frame of reference:

Frame of Reference:
"The paper will not be an orthodox situation analysis, but will provide instead both an impressionistic and predictive analysis on the environmental factors affecting children's development and well being in the region" (email from Andrew Timpson, 2002).

As part of her analysis, Dr. Vogel will be asked to consider the following issues:

- *What within the natural environment could worsen the vulnerability and poverty of children within the region? e.g.*
- Climate change and its effects—encompassing an analysis on drought, floods, coastal cyclones etc.
- Inter-governmental co-operation on dam and river management.
- The future role of SADC in environmental management
- The likely links between environmental change and HIV
- The environmental effects of rural migration into urban areas.
- The likely impact of environmental change on regional food security.

A report that provides meaningful answers and useful information on all these topics is not possible given the complex nature of the issues, time frame for the study and state of the science to date. Several of these issues are indeed the work of major international research projects (e.g. the International Geosphere-Biosphere Programme, (IGBP); the International Human Dimensions Programme on Global Environmental Change; World Meteorological Programme and Diversities; the Millennium Ecosystem Assessment including sub-global assessments for southern Africa; the Intergovernmental Panel on Climate Change, IPCC) and the ongoing efforts of several other initiatives e.g. NEPAD (www.nepad.org).

While every attempt has been made to cover most of these issues, the focus in the report is on the biophysical aspects of the environment with some attention given to the interactions between these and some human dimensions issues e.g. HIV/AIDS, migration etc. A lack of detailed information on institutional issues e.g. SADC and environmental management has resulted in this section being omitted from this final report. Brief mention is, however, made of HIV/AIDS and migration. For more details on HIV/AIDS see the Whiteside report done for SCF.

---

1 The SADC region for SCF is all of SADC with the exception of Tanzania, the DRC and the Seychelles.

What is provided in this report (together appendices) is therefore an overview of some of the key issues raised in some of the global change science efforts outlined above, together with other sources. Finally, some suggestions for further consideration, particularly as it may impact SCF work in the region, are given.

The report is divided into three parts. Part 1 is an overview of some of the biophysical impacts facing the region. Part II identifies some of the human dimensions facing the region including HIV/AIDs and finally in Part III some suggestions for mitigation are provided.

INTRODUCTION

The environments of southern Africa are characterized by variations in rainfall, hydrology, natural resources and agricultural potential. Regional and within country variations in climate, for example, occur both across varying temporal and spatial scales (e.g. periods of drought, in some cases extreme, followed by periods of above-normal rainfall and floods). Reports of land degradation, deforestation and declining ability for the region to feed itself are often made (e.g. Global 2000 Report; Lomborg, 2001). Sub-Saharan Africa, for example, is estimated to have the largest numbers of starving people (even before the current food emergency)—almost 33 per cent were starving in 1996.

Despite these indications of starvation and current food emergencies, the agricultural potential is largely untapped (Global Report, 2000). Recent preliminary assessments, that form part of the Millennium Ecosystem Assessment (see for example, the Southern African Millennium Ecosystem Assessment, SafMA, 2002) and using a range of data sources (e.g. FAO data, bio fuel consumption rates, population data, maximum crop yields etc), for example, show that despite a few pockets of deficits in some areas, cereal supply exceeds demand for much of the region (see Appendix, Figs. 1-3). Of interest from these figures, particularly Fig. 2 of cereal demand and supply, is that we should essentially be able to feed ourselves in the region. The current emergency, however, stands in contrast to these *national food statistics* estimations, pointing yet again to the human dimensions of this emergency. Droughts in the region, together with conflict, political instability, high food prices, the impact of HIV aids and other factors that limit people's access to food (e.g. Sen, 1981) are some of the factors that are heightening the *household food* security in the region. Indeed some have suggested that the problem is not a lack of agricultural resources in the region but the lack of political momentum and will to tackle poverty head on, bureaucratic inertia and lack of capacity to intervene effectively (UNDP 1977 as cited in Lomborg, 2001 and Deveruex, 2000a).

With this as background, environmental scenarios that may face the region are traced. These scenarios reflect scientific work that is based on models essentially capturing possible impacts associated with climate variability (e.g. ENSO etc); impacts on vegetation and water in the region. Included in this analysis, is some discussion on the interacting human factors (e.g. HIV/AIDS impacts; migration etc) but, as indicated earlier, these are not fully discussed because they have been the focus of other commissioned reports. These interactions are critical, however, and must be heavily underscored and remembered when reading this report.

PART I—SOME OF THE BIOPHYSCIAL CHANGES THAT MAY ENHANCE OR DEGRADE THE ENVIRONMENT

- **Changes in rainfall and other climate parameters will impact the region**

Global environmental change is a topic that has recently been under considerable review (e.g. IGBP, 2001; IPCC, 2001). Cumulative evidence gleaned over the past few decades indicates that planetary changes are occurring rapidly (IGBP, 2001). These changes in turn are acting as feedbacks that all combine to drive the Earth System. Mean annual temperatures have, for example, shown a marked and rapid increase particularly over the past century. Nine of the ten warmest years (1860-present record of data maintained by member of the World Meteorological Organization, WMO) have occurred since 1990 with one of the warmest years being 1998 and 2001 the second warmest (Climate Research Unit and Met Office, UEA). These conditions have been identified as being part of a trend to warmer global temperatures that have resulted in a rise of more than 0.6º C during the past 100 years. The rise in temperature, however, has not been continuous. Since 1976 the global average has nonetheless risen at a rate approximately three times faster than the century-scale trend (WM0, www.wmo.ch/web). A number of impacts may result from these changes in atmospheric conditions including possible changes in vegetation, surface water availability, rangeland condition etc. Some of these impacts are discussed below.

- **Climate variability in the region, including droughts and floods may be more important in the near-term in the region than longer-term climate change**

At present no single method exists for producing confident predictions of future climate and therefore climate scenarios are usually used (Perks et al., 2000). Cane (a leading modeller of climate systems) suggests that "The forecasts are far from perfect, especially so for the connections to local conditions with the greatest human consequences" (Cane, 2000). Using Global Circulation Models (GCMs) and other indicators (e.g. development of ENSO, El Niño/La Niña) scientists are, however, able to offer probabilistic forecasts of what may be expected for the next season and possible scenarios from which impacts associated with climate change can be gauged.

GCMs, or Global Circulation Models, are types of models that are used to drive various outlooks or scenarios of possible future environmental changes that may be associated with warming. Establishing detailed climate and other environmental changes at a regional scale and for specific areas and places is, however, difficult to obtain from current GCMs. This is because of the uncertainties of the climate system when trying to reduce or 'downscale' the scenarios generated from the models to the regional and local scale as well as trying to include all the dynamics of the system. Different GCMs, for example, focus on different aspects (for example one may allow feedbacks from the earth-atmosphere system via sulphates in the model run, others may couple oceans and the atmosphere while others may include the feedbacks and inter-actions of ecology etc.) (Rozensweig and Hillel, 1998).

At present a number of models are used. Those used for the southern African region include GENESIS (Global Environment and Ecology Simulation of Interactive Systems); Hadley Model; and CSM (Climate Systems Model). Using a variety of such GCMS and other techniques (e.g. statistical techniques etc) the following scenarios have been provided for the region.

☞ Some climate change scenarios for the region

Using some of these models, and mindful of the constraints and limitations of using these outputs, various assessments (e.g. Joubert and Tyson, 1996; Joubert and Hewitson, 1997; Mason and Joubert, 1997) have been made for the region. One indication from the models that may impact on SCF and its work in the region is that variability and the frequency of extreme events are likely to be extremely important in the region. Using the CSIRO9 model Mason and Joubert (1997), for example, found that changes in the number and frequency of extreme rainfall events may be more important than the mean changes in rainfall. Although there are a variety of possible outcomes suggested from these models (Table 1) there still remain uncertainties about obtaining rainfall estimates from GCMs (Hewitson, pers. Com, 2002). These assessments and scenarios can also vary, however, depending on the type of GCM model used. Despite these shortcomings models give some indication of possible environmental changes.

Assessments (e.g. US Country Studies Reports, essentially country studies for most countries in the region were undertaken see www.gcrio.org/CSP/africa.html for reports relating to Malawi, Botswana, Zimbabwe and other areas) show that for South Africa, Lesotho and Swaziland, and depending on the model used e.g. either GENESIS or Hadley, variations of outcomes can be described. The Hadley model, for example, describes general decreases in rainfall in the study area whereas the GENESIS model describes increases in rainfall relative to the present (see Perks *et al.*, 2000 for more details). Other indications from models used (e.g. UKTR95 GCM) show an expected annual rainfall increase of 30-35% over all of Kenya, with smaller increases (up to 30%) over most of Tanzania, Uganda and north eastern Zambia and very slight increases over smaller areas of western Zimbabwe, Botswana and Namibia (Schulze, Meigh and Horan, 2001). This is in contrast to decreases in annual rainfall south of Tanzania, (between 10% an up to 30% in places).

Table 1: Examples of possible indications of climate change derived from various models and sources (including Shackelton, Lennon and Tosen, 1996; Joubert et al., 1996; Bridgman, 1998) for the region and particularly for South Africa.

- The increase in temperature will be dependent on latitude.
- The increase in temperature will be greater in the winter rainfall area than in the summer rainfall area.
- The role of the escarpment is important in shaping expected rainfall and other dynamics of the climate system
- *Rainfall (uncertainty surrounds estimates of future rainfall under a doubled carbon dioxide scenario than temperature*).
- Overall fewer rain-days are expected, rainfall intensity will increase (implying greater runoff).
- Increases in rainfall likely in summer rainfall, with more intense events
- More convective activity in winter rainfall areas.
- The seasonality of rainfall is unlikely to change and mean annual totals should only vary slightly.
- Rainfall is likely to increase slightly in the tropics (by <10%) and decrease somewhat in the east-central interior by about (10-20%) (Joubert and Tyson, 1996).
- For drought periods the model indicates increasing probabilities of dry spells or dry years in the tropics, to the south-west of the subcontinent and especially over western South Africa and over eastern southern Africa including Mozambique (Joubert et al., 1996; Bridgman, 1998).
- Finally, Hulme analyzing three regions of Africa suggests a wetting in East Africa, drying in southeast Africa and a poorly specified outcome for the Sahel (IPCC, 2001, 494).

- **Examples of possible changes in agriculture that may be associated with changes in temperature and rainfall as linked to greenhouse warming**

Impacts on food production in a changing and more variable climate have been shown to be linked to changes in temperature, moisture levels, ultra violet radiation, changes in CO_2 levels, pests and diseases both in the past and in model simulations. The droughts of the early 1980s and 1990s, for example, seriously impacted the southern African region reducing cereal production and water supplies with resultant impacts on GDP (e.g. largely as a result of drought, manufacturing output in Zimbabwe, for example, declined by 9.5% in 1992 and in South Africa the drought necessitated maize imports totalling US$604 million). The knock-on impacts e.g. loss of farm workers jobs and the reduction of overall livelihoods for many have also been noted (for a detailed assessment of the economic impacts of drought of the mid-1990s see Benson and Clay (1998)). With these realities and a growing food emergency currently evolving in the region, it is useful and essential to explore what the environmental scenarios, using the current science, may be in the near- and long-term future.

- **Shorter-term possible impacts on agriculture. The development of an El Niño, *may mean that rainfall may vary in the forthcoming season* with possible impacts on agricultural production in the region. *This condition cannot be reliably determined at present (for reasons outlined below) and readers are advised to monitor this situation more closely.***

At a regional level, indications for seasonal rainfall and temperature (possible rainfall and temperatures) that may be expected over the coming season are given, based on various techniques, including GCMs and statistical forecasting methods. Various Seasonal Climate Outlook Forums convene several times before and during the rainy seasons to offer a consolidated 'outlook' for regions. Two of these are pertinent here, viz. the Climate Outlook Forum for the Greater Horn of Africa and the Climate Outlook Forum for Southern Africa (the next SARCOF Forum is to be held in Harare in September, 2002).

Some of the key factors that are considered by these Forums are the SSTs (sea-surface temperatures) in the tropical Pacific and how those over the tropical Atlantic and Indian Oceans may influence regional seasonal rainfall. Monitoring SSTs in these regions and associations with the build up of El Niños and La Niñas have been shown, at times, to influence climate and particularly seasonal climate in certain areas of southern and eastern Africa (see e.g. Glantz, 2001).

While it has been shown that such techniques and methods show some good predicative skill the point, however, must be made that such 'outlooks' *may not fully account for all the physical and dynamical factors that influence regional, national and local climate variability* (see for example, Landsea and Knaff, 2000 and Barnston, Glantz and He, 1999). The biophysical responses to El Niño and La Niña (e.g. rainfall and temperature) vary spatially and with time (Mason and Landman, 1999) for South Africa. Despite this variability in cause and effect, El Niño events are usually associated with below-normal rainfall over land, whereas La Niña events may result in a wider extent of above-normal rainfall (see Mason and Goddard, 2001).

Warming of the Pacific Ocean and associated teleconnections to rainfall in southern Africa is not the only aspect that is considered when examining ENSO impacts for the region. Sea-surface temperature anomalies of the Indian Ocean are also related to southern African seasonal rainfall (e.g. Landman and Mason, 1999). Warmer (cooler) than average sea-surface temperatures in the Agulhas system, for example, are usually associated with wetter (drier) than average rainfall over the summer rainfall region of South Africa.[2] "Over the most recent decades, however, sea-surface

[2] Anomalously warm-sea surface temperatures in the central and tropical western Indian Ocean have also been associated with drier than average conditions over South Africa. Since the late 1970s, the sea-surface temperature variability has been characterized by increasing temperatures in the equatorial Indian Ocean. Furthermore, the ENSO signal has been shown to have weakened in the Indian Ocean sea-surface temperatures since the late 1970s, and this has resulted in a change in the association between Indian Ocean SSTs and December-February rainfall over much of South Africa and Namibia. Prior to the late 1970s, sea surface temperature variability in equatorial Indian Ocean was closely related to ENSO and equatorial SSTs.

temperature variability in the tropical western Indian Ocean has become significantly less dependent on ENSO" (Landman and Mason, 1999, 1490).

> "The recent changes in the association between tropical western Indian Ocean sea-surface temperature and rainfall over parts of southern Africa, the apparent ability of sea temperatures in the region to modulate the influence of ENSO events on rainfall over the country, and the ability of sea-surface temperature variability to occur independently of El Niña and La Niña events, all emphasize the importance of including the area in both statistically- and dynamically-based seasonal forecasting models" (Landman and Mason, 1999, 1490, emphasis added).

The outcome of the ENSO event for southern Africa, of 1997/98 was, for example, partly influenced by the developments in the Indian Ocean. Before sudden and drastic decisions regarding food relief and other emergency measures are therefore taken, it is essential that the developments of ENSO are closely monitored as well as those developments in the Indian Ocean that may influence the magnitude of such an event.

Some of the more recent indications for current climate outlooks (e.g. NOAA, National Oceanic and Atmospheric Administration, USA and IRI, International Research Institute for Climate Prediction, Columbia, USA) include an examination of the SSTs in the tropical Pacific and potential development of an El Niño or La Niña situation. These are usually issued monthly and are based on a consensus of models that forecast ENSO (El Niño Southern Oscillation) developments for the coming 6 or more months. From recent assessments, there would appear to be indications that warming of the central equatorial Pacific is occurring:

> "This behaviour has been observed prior to the onset of many past El Niño events. However, based on historical observations and the performance of computer models at this time of the year, it is not certain if the expected warming in the eastern pacific will lead to a Pacific basin-wide El Niño. Thus, while the current ocean conditions exhibit the necessary early conditions for El Niño, there continues to be substantial uncertainty over whether El Niño will develop in the next few months. The evolution of the system in the next few months or two will likely make possible forecasts having more certainty" (IRI, http://iri.columbia.edu/climate/ENSO/).

Recent indications (see http://iri.columbia.edu/climate/ENSO/, El Niño Alert issued July 17th 2002) are that ocean conditions in the tropical Pacific have currently reached the minimum level required to represent the onset phase of El Niño. There is a 90% probability that these conditions will persist for the next 6-9 months, indicating a high likelihood for a fully developed El Niño for the remainder of 2002 and continuing into early 2003. The forecast SSTs in the tropical Pacific are, however, significantly less than those associated with 1997-98 El Nino. Climate impacts are "anticipated to be weaker than those associated with the 1997-98 but may be substantial in some regions" (http://iri.columbia.edu, El Niño Alert, July 17, 2002).

The timing of El Niño and rainfall seasonality for the region is also important aspects to consider. Over South Africa, for example, the influence of ENSO events on rainfall is strongest during the summer peak rainfall months (i.e. December to March) when ENSO events have typically reached maturity and when the tropical atmospheric circulation is usually dominant over this area. Further north, e.g. over Zimbabwe, the early- and late-seasonal rains (e.g. October and March) are more severely affected than the mid-season (Mason, 2001). Early indications of El Niño therefore need to be updated with reference to the rainfall patterns in the region i.e. closer to the rainfall season. The development of El Niño therefore needs to be tracked (see http.//iri.columbia.edu).

Using these scenario outputs various seasonal outlooks for Southern Africa are given. For countries in the Greater Horn of Africa consult (www.cpc.ncep.noaa.gov) for those in southern consult Drought Monitoring Center (www.dmc.co.zw) and/or the South African Weather Services (www.weathersa.co.za). The seasonal forecast is given as a probability for categories (above, near, below-normal) for both temperature and rainfall (see Appendix for an example of such a forecast). The category with the highest probability is the most likely to occur. A forecast for above-normal rainfall, however, does not necessarily mean a good season. Rainfall timing, when and how much can also make a difference, particularly for agriculture (LOGIC, 24-01-2002).

Several problems still frustrate forecast efforts including suitability for users, 'down scaling' of the forecast for area-specific usage, reliability of the forecasts etc. (Goddard et al., 2001). Mid-season droughts or dry periods, for example, can heighten and aggravate below-normal conditions particularly for farmers. Usually a mid-season 'correction' or update is given for the forecast but these may come too late for users. Unusually dry conditions, for example, have prevailed across portions of south-eastern Africa since Jan 2002 despite the indications of an essentially 'normal' season (see Appendix). Above- normal temperatures have also prevailed in several parts of the region. Together these conditions are stressing crops:

> "….no relief is expected across the region throughout the period. The dryness is expected to increase moisture deficits during the period, therefore worsening the drought conditions" (Chester V Schmitt, Climate Prediction Centre, www.cpc.ncep.nooaa.gov).

While droughts are a key hazard to monitor in the region, for some areas, including the eastern coastal areas and Mauritius, cyclones are another important atmospheric feature to track. The southwest Indian Ocean cyclone season runs from September to May, with the most active months being January and February. This year is expected to be a normal cyclone season (on average of 12 cyclones per year) (Regional Flood Watch, 25 Jan 2002). Having said this, the role of the Indian Ocean in modulating Southern African rainfall, however, remains a critical component in explaining climate and weather in the SADC region and therefore merits further monitoring and assessment.

Having provided a discussion of some of the current concerns of climate variability in the region, attention now shifts to some of the potential impacts including agricultural, vegetation and hydrological impacts that may constrain livelihoods in the region.

- **Longer-term possible impacts on agriculture in parts of the region using a variety of models**

In South Africa, several attempts have been made, using various models, to generate scenarios of possible future impacts associated with global warming. The ACRU/CERES (e.g. Schulze et al., 1996) models and the Hadley, Genesis and Climate System Models (e.g. Du Toit et al., 2000) have been used, for example, to assess the potential impacts of changes climate on crop growth (in this case maize production). For these models and scenarios, a range of outcomes is generated depending on the models and data used. Of interest to this report, however, is that most of these models indicate some decreases in yield towards the west of South Africa (with severe reductions indicated in the use of the Hadley scenarios (e.g. Du Toit et al., 2000), but for most of the country potential yield could increase, in some cases, by as much as 5 t/ha (e.g. Hulme, 1996; Schulze, et al., 1996).

Generating scenarios of cereal production, using models, is difficult and variable results can be obtained depending on the model and data used. In Zimbabwe, for example, impacts on maize production have been examined using scenarios generated by GCMs and crop simulations (Muchena and Iglesias, 1995; Matarira et al., 1996). Reduced yields are noted for several areas in Zimbabwe. Some suggest (e.g. Matarira et al., 1996) that under a double CO_2 scenario, a 15 to 19% decrease in rainfall is noted and with an increase in evaporation, a 50% decrease in runoff is estimated. One of the key vulnerabilities will then be the decrease in the yield from dams with impacts on agriculture. Decreased maize yields of about 30-40% (in areas of Zimbabwe) have also been noted with some scenarios (Matarira, 1996). Climate variability may, for example, turn low-lying areas into non-maize areas with changes to growing season, planting times and yield (e.g. Muchena, 1994; Matarira et al., 1996; Makhado, 1996).

Livestock is also closely linked to rainfall and changes in annual precipitation. Changes in rain-fed livestock numbers in Africa are and will be closely coupled to changes in annual precipitation. Given that several GCMs predict a decrease in rainfall (10-20%) in the main semi-arid zones of Africa, there is a real possibility that climate may have a negative impact on pastoral livelihoods (IPPC, 2001). Diminished grassland area by encroaching trees (with enrichment of CO_2) may also place additional stress on livelihoods derived from rangelands.

- **Rangeland and other vegetation changes associated with warming in the region**

Rangelands

Several models have been used to indicate possible changes in rangeland condition and production, with suggested gains and losses in yield in some areas. While some indicate negative changes e.g. possible enhanced degradation others indicate possible positive changes. In terms of vegetation and land use, the SADC region is very heterogeneous. Commercial and communal rangelands and irrigated and rain-fed agricultural predominate in the region. Generally the rangelands dominate in the drier more western areas of the region while arable farming flourishes under moist conditions and under irrigation (Hulme, 1996). The rangelands, moreover, are an important livelihood source for several rural communities and commercial farmers. Changes in the rangelands are therefore important to consider.

Table 2: Summary of possible human impacts of climate change in Botswana (after Hulme, 1996, 69). (Core scenario sees modest drying over large parts of the region; dry scenario region experiences a decline of up to 20% and a wet scenario in which most of the regions get wetter Hulme, 1996, ix).

Impact type	'Core' scenario	'Wet' scenario	'Dry' scenario
Sectoral Shifts	Desert expansion reduces livestock potential in favour of small stock and some wildlife species.	Little change, possibly better cultivation opportunities.	Desert expansion reduces livestock potential in favour of small stock and some wildlife species.
Productivity and income by sector	Increase in marginal conditions adversely affects land productivity in large areas.	Little change; small increase in cultivation.	Increase in marginal conditions adversely affects land productivity in large areas.
Livelihood security/income distribution	Widespread reduction (extreme events; poorer physical conditions).	Reduced severity (extreme events).	Widespread reduction (extreme events; poorer physical conditions).
Development potential/carrying capacity	Decrease, with some differences between regions.	Same or slight decrease.	Decrease, with some differences between regions.

Using a 'mental model'[3], such as that outlined above (Table 2), Hulme (1996) suggests three scenarios that may occur in the region under climate change. For all of the cases the 'wet scenario' is associated with increased temperature and increased rainfall and the 'dry and core scenario' is associated with increased temperatures and decreased rainfall. As is evident, the impacts flowing from these changes may impact on household livelihoods and may reduce the quality of life of children in the region.

Scholes, Midgely and Wand (2000), in their more recent study on vulnerability and adaptation of rangelands in southern Africa, show that general aridification of rangelands may occur over much of southern Africa, particularly in marginal environments subject to drought. They conclude that climate change impacts may, however, be complicated by rising CO_2. The grassland biome may become more favourable to tree growth due to elevated CO_2.

[3] This is a deliberate choice, using a mental rather than a mathematical model because of limitations of data, large uncertainties in the interactions between physical and social responses to regional climate change over the next 60 years and the complexity of the issues under review (Hulme, 1996, 63).

Other assessments of possible vegetation changes and impacts on plant diversity have also been done for South Africa, in particular Succulent Karoo Bioclimate Modeling (see www.nbi.ac.za./climrep/index). Here again various models were used (e.g. HadCM2, CSM and GadCM2 (i.e. essentially models that either includes the influence of sulphates or not in their computations). Essentially, bio climate modelling determines the environmental limits of an entity with a given spatial distribution by matching its known distribution to climatic surfaces (www.nbi.ac.za). Indications from this bioclimatic modelling show virtual complete loss and disappearance of the Succulent Karoo Biome and expansion of the Savannah Biome into the Grassland Biome areas. Tree encroachment in the grasslands may in turn mean that grass production is suppressed placing a stress on those depending on the grasslands for livelihoods. An increase in diversification of livelihoods for such groups including activities such as ecotourism, to offset these potential negative impacts, is suggested.

- **Implications for water supplies and availability in the region in a changing environment**

Coupled to vegetation and biome changes is available water. As is clear from some of the model assessments presented above, the indication is that rainfall may increase in some areas and decrease in others depending on the model used. While this may not be very useful to SCF practitioners currently, at least an indication of possible changes in the environmental system can be suggested that may shape future management decisions. As previously indicated, rainfall and run-off assessments have been derived for a 2050 climate scenario using the UKTR95 GCM with marked increases (30-50%) in expected annual rainfall over virtually all of Kenya, smaller increases (30%) over most of Tanzania, Uganda and north-eastern Zambia and very slight rises over smaller areas of western Zimbabwe, Botswana and central Namibia. This is in contrast to those areas with general declines in annual rainfall south of Tanzania, generally in the order of 10% but up to 30% in places.

Mainly as a consequence of anticipated changes in rainfall, including extreme events, changes in frequency and intensity in rainfall, the UKTR95 scenario for 2050 shows decreases in annual runoff of the order of 0-40% over much of South Africa, and over 30% over eastern Zimbabwe and most of Mozambique. Enhanced runoff may be anticipated over northern Zambia and Mozambique as well as over eastern Tanzania, with the most significant increases predicted for Kenya (Schulze, Meigh and Horan, 2001).

Water stress in the region is, however, not only a function of rainfall and other biophysical variables (e.g. evaporation) but also includes such factors as population growth, expanding urbanization and increased economic development as well as various challenges to international water resources (Sharma et al., 1996). Water demand, for example, is projected to rise by 3% until the year 2020, a rate about equal to the region’s population growth rate (SARDC, IUCN and SADC, 1994). By 2025 it is estimated that a number of countries in Africa, several of them in the region, will experience severe water stress (World Bank, 1995). The implications for changes in water availability for the region are therefore critical considerations particularly when viewed against the backdrop of possibly climate variability in the region that has been described above.

Accurate and precise estimates of water vulnerability in the region, however, cannot be given. By using models that try to best capture as many of the variables that may play a role in determining water availability in the region, some indications of water availability can be suggested. More recent hydrological assessments (e.g. Schulze, Meigh and Horan (2001) include the development of an index that accounts for seasonal and inter-annual variation of supply of water, combines both surface and groundwater availability and adds the human dimensions by including supply and demand of water. Using the index, an assessment of the vulnerability of the eastern and southern Africa's (ESA) hydrology and water resources was made. Under current demands, much of ESA was shown to have adequate water supply. Many areas have groundwater supplies that are as yet untapped in the region. Water shortfalls, however, were shown to exist mainly in Uganda, south-western Kenya, in Zimbabwe around Harare, and over much of South Africa, Lesotho and Swaziland (largely a consequence of high urban population densities combined with high irrigation demands in these areas) (Meigh et al., 1998).

Expanding on this work, and by including such factors as projected population growth, demand increases in water-use sectors (rural, urban and large urban), as well as changes expected with a model output for future climate (UKTR95), a scenario for 2050 was undertaken. By 2050 water shortages are expected to increase with the biggest shortage projected for Mozambique, Tanzania and South Africa. Increases in areas with severe water shortages, where shortages are projected to increase, include South Africa, Tanzania and Uganda.

The potential increase in extreme events (such as droughts and floods), as indicated above, may place additional strains on already water-stressed areas. The case of the impacts of the 1992 drought, for example, is informative on the impacts that such an extreme climate event may have on a country. Using the early 1990s drought as an analogue, Magadza (1996) illustrates, that under a $2XCO_2$ scenario, lakes, dams and wetlands would be impacted. Evaporation would increase with many of the small impoundments of water either drying up or holding insufficient water for local needs. Investigations, for example, in Lake Mtirikwe (formerly Kyle) during the 1991/92 period, showed that reductions in rainfall following years of persistent low water levels resulted in reductions of water for irrigation for sugar estates and were too low to maintain water supply to the Masvingo urban area. Additional problems of salutation, among others, for example, could further heighten such periods of environmental stress (Magadza, 1996). For other related or 'knock-on' impacts arising due to shortages in water in the region see Benson and Clay (1998).

Table 3: Some factors influencing the vulnerability of ESA water resources, now and in the future (adapted from Schulze, Meigh and Horan, 2001).

Factor	Explanation
Spatial variation	Vulnerability of water resources can vary markedly over a short distance
Lack of physical infrastructure	A lack of infrastructure inhibits optimal use of water
Settlement location	Many rural dwellers are not located along perennially flowing river channels
High variability of runoff within and between seasons	High costs of water projects because of high variability in the hydrological system
Food security	Climate and hydrological uncertainty constrains self-sufficiency of food.

PART II—SOME OF THE HUMAN DIMENSIONS OF CHANGE THAT MAY ENHANCE OR REDUCE THE BIOPHYSICAL CHANGES SUGGESTED

Possible changes in the biophysical environment associated with global environmental change have been illustrated above. For the southern African region, however, these form the stage upon which the human dimensions of change are enacted including those associated with HIV/AIDS, political instability, problems of good governance, globalisation and other economic changes. At the time of writing this report several accounts of the harsh reality of a food emergency influenced by drought and floods but also high prices for basic commodities, political instability in some areas, depleted grain reserves and other headlines appear daily in the media (e.g. "The Politics of Hunger", Mail and Guardian, July 19-25, 2002). As indicated at the outset of this report, the details of such interactions in 'the politics of hunger' were not the precise brief of this report but their importance and influence on the environment merit at least some brief discussion.

➢ The impacts of HIV/AIDS on the environment

One of the biggest obstacles to sustainable development in Africa (see for example some of the UNDP papers on this topic, www.undp.org/hiv/publications) (Table 4) is HIV/AIDS. The epidemic is also seen to be a hindrance to achieving some of the goals set in the UN Millennium Declaration (Loewenson and Whiteside, 2001) (Table 4). Several countries in the region are estimated to be affected by HIV/AIDS, for example, Botswana (35.80%), Swaziland (25.25%), Zimbabwe (25.06%), Lesotho (23.57%), Zambia (19.95%) and South Africa 19.94%) (Loewenson and Whiteside, 2001).

The human impacts of HIV/AIDS are numerous. Impacts on the environment as a result of HIV/AIDS (as per the brief for this report) are also numerous with several not yet fully understood. Some of the impacts on the environment and vice versa, as a consequence of HIV/AIDS, particularly for children, (e.g. Table 4) include increased numbers of the poor being unable to afford housing; seeking housing in marginal areas in those areas that may be possibly hazardous e.g. in flood line areas; drops in agricultural production; poor governmental service delivery in basic infrastructure and the associated increase in cases of cholera. Some of the more obvious environmental linkages that have been examined and that are relevant to this report are those relating to rural farm-children and farming systems (e.g. du Guerny, 1998).

Table 4: Selected UN Millennium declaration goals and the effect of HIV/AIDS (Source: Adapted from Loewenson and Whiteside, 2001).

Millennium Development Goals	Effect of HIV/AIDS
Reduce income poverty (halve by 2015 share of the world's people whose income is less than 1 $ a day	AIDS increases consumption needs and depletes household assets. Labour losses reduce income (can push household incomes down by 80%).
Reduce hunger (reduce the proportion of people who suffer from hunger)	Illness, reduced incomes, lower productivity of subsistence agriculture and crops increase food insecurity, especially for women and children. Food consumption in households falls by 15-30%.
Increase access to safe water (by 2015 halve the proportion of people who are unable to reach or afford safe drinking water)	Illness, increased labour demands for caring and lost labour time for collecting water, especially for women. Human resources losses and costs in water supply services affect delivery and increase the cost of services to households.
Universal primary education (by 2015 children able to complete a full course of primary schooling)	Education supply threatened by teacher absenteeism and deaths. Can lead to 20-40% reductions in primary school enrolment.
Improve child health (reduce under-five child mortality by two thirds of its current rates 2015)	Infant and child mortality continue to increase for the next decade, possibly longer.
Achieve gender equality (girls and boys to have equal access to all levels of education)	Girls are more likely to be kept out of school to provide care or when resources limited.
Improve lives of slum dwellers (by 2020 achieve a significant improvement in the lives of at least 100 million slum dwellers	AIDS reduces the ability to afford even the most basic housing by the poor. Pushes new households into poverty and reduces service delivery by governments.

Using the farm household system approach, du Guerny (1999), for example, traces the impacts on both the household and the farm system of HIV/AIDS, some of which include:

- Reduction in area of land under cultivation
- Declining yields
- Decline in crop variety and changes in cropping patterns
- Decline in livestock production
- Loss of agricultural skills
- Impact on food security
- Heightened vulnerability.

Using such an approach, some impacts associated with HIV/AIDS can be postulated. An estimated 7 million agricultural workers since 1985 have died from AIDS in the 25 hardest hit countries in Africa. The impact and tragedy of these deaths are, however, not only borne by the immediate families but also have other knock-on effects (both nationally e.g. possible impacts on GDP in agriculture and also as indicated in Table 4 on certain household members e.g. women and children). Women whose husbands are migrant workers, are especially vulnerable through partners who may have other sexual partners; they may lose access to land amongst other outcomes.

Other nuances of possible impacts resulting from increased HIV/AIDS are those linked to the use of the environment. Illness and death associated with AIDS can reduce labour time (funerals), and hence less time to tend to agricultural and other activities; livestock management skills are lost; decreased management of livestock resources; crop failures including fodder reductions for livestock; decreased livestock products; loss or transfer of livestock (and in cases small stock e.g. chickens) from families; and associated overall loss of livelihoods (e.g. see Engh, Stloukal and du Guerny, 2000).

Finally an area where HIV/AIDS can have an immediate impact on communities and more particularly children, is by weakening humanitarian efforts during emergency situations such as that persisting in the region. Further reduced capacity in the region (several NGOs are already increasingly being pressurized to carefully consider relief efforts as they become constrained by possible conflict, mismanagement of funds and other problems) by AIDS, could disrupt future interventions and ongoing mitigation in the region.

- **Migration within the region and the impacts on the environment**

Another human-dimension issue in the region is that of migration and refugee movement. The issue of migration (both urban and rural), much like those highlighted above, is also complex in the southern African context. Movements of people between regions and areas, particularly those precipitated by conflict and other factors are an important concern for the southern African region. UNCHR estimates the 2002 refugee population in all Africa at approximately 3.3. million people, of which almost one third are hosted in SADC countries. Almost 90% of refugees are in Tanzania, DRC and Zambia. The UNHCR believes that the number of refugees will increase during 2002 (FEWSNET and SCF, UK 2002) but may be further aggravated by the growing food emergency.

- **Compounding impacts associated with migration is the risk of increased disease.**

If large numbers of refugees move, then additional stress may enhance vulnerabilities in the region. People displaced from their normal environments, weakened by hunger and crowded into refugee camps with often poor health facilities may raise the risk of such diseases as cholera, measles and other diseases (see for example de Waal, 1989). Despite the lack of detail that could be found on some of these consequences for the region, a local example from SCF points to some of the issues faced.

A rapid household assessment in Chihwiti and Gambuli informal settlements in the Makonde district, Mashonaland West during September 2001, highlighted some of the impacts associated with refugees (SCF and Farm Community Trust, 2001). Chihwiti has been receiving a number of new settlers ‘every week’ (estimates of 100 per week), many farm workers displaced as result of the current land reform programme, and there are concerns that “At some point the carrying capacity of the land will be exhausted, and the ability of existing settlers to support individual new comers will also be exhausted” (SCF and Farm Community Trust, 2001, 17). The recommendations included for this area in particular were to continue to closely monitor the situation, to note that the nature of the displacement will vary and to avoid only targeting new comers to the area (SCF and Farm Community Trust, 2001) for interventions and relief.

In some cases, it would seem, that falling gold prices, growing retrenchments, increased crime and xenophobia have acted as potential detractors to migration in the region. Despite these possible detractors, one of the most significant changes in cross-border migration in South Africa, for example, has been the dramatic increase in non-contract migration outside the mining sector (McDonald, 1999). Documented border crossings have increased almost seven-fold to over 3 million visitors a year since 1990. Undocumented migration has also increased, particularly from Mozambique (Minnar and Hough, 1996; Crush, 1997).

The focus of migration, with reference to this report, is whether migration may have an impact on the environment and whether the ‘state’ of the environment may impact on migration. In assessing this issue one needs to approach it from two perspectives. Migration, both urban and rural, is influenced by various socio-economic factors (e.g. employment, unrest and conflict) and biophysical factors (e.g. severe drought and floods). There is some evidence to suggest, for example, that periods of natural stress (such as floods and droughts) may induce some people to move so that they can avoid loss of life and livelihoods. Migration in the southern African region, however, has also had a strong historical dimension that exhibits the influence of a number of socio-political factors at play (e.g. pools of cheap labour to farms and mines in South Africa) in the region. A detailed investigation of both the historical context and current drivers of migration is therefore recommended.

One are in which migration may have an effect on the environment is through increased pressure on resources and the environment in general. Increasing demographic pressures as a result of migration, and other factors, can intensify changes in the environment. Marginal lands are sometimes occupied, but these may over time, decrease in productivity owing to increased pressures on resources. The debates on trends between population and degradation are, however, legion. Of interest to this report, however, are the suggestions that indigenous and other agricultural resource management practices, which evolved to suit historical rainfall patterns, may no longer be sustainable for a variety of reasons (see below). Thus vulnerabilities to varying climates (e.g. droughts and floods) associated with increased demographic pressure, may increase in the short term, before households and economies adapt to changing climate conditions (see Davies, 1995 and Benson and Clay, 1998).

As can be seen from the discussion, migration and the links to the environment are complex. A detailed analysis of migration, refugee movements and the environment, including impacts on children, therefore should be undertaken.

- **The current complex emergency in southern Africa and possible future outcomes**

The final section of this report includes a brief examination of food security and the food emergency in the region. Food security in the region is a function of biophysical ‘drivers’ or factors (e.g. rainfall, temperature, evaporation, climate, soil, surface and underground water) that govern food for consumption. Food security, however, is also very closely linked to those ‘human’ dimensions including markets, production, access to infrastructure and other resources e.g. seeds, irrigation, financial loans and a host of socio-political factors including the role of various institutions and policies that may influence food security. Most working in the food security arena acknowledge that these factors define what food there is at a given time and more importantly who gains *access* to food. In this final section, one cannot therefore unpack all these dimensions to food security and only some are identified.

In most of SADC countries at least 70% derive a livelihood from agriculture (Buckland, 1994). Data from Zimbabwe illustrates the nexus of deviations of rainfall (both in terms of total precipitation and timing) and food security. Between 1960 and 1992, for example, average annual rainfall for Zimbabwe was 662.3 mm. Of available maize yield data (e.g. 1969-1992) the yields parallel the changes in annual rainfall (2,4 t/ha recorded in 1986; and 0,4 t/ha in 1992 a severe drought year). More critical than the obvious shortfalls, associated with rainfall decreases in dry years, is the marked variability in both rainfall and maize production, highlighting clearly the very ‘risky’ environment in which several farmers (particularly small-scale farmers) operate (Buckland, 1994). Rainfall is, however, not the single determinant of maize yield and other considerations such as some of the other human-dimensions highlighted above, should also be considered (as is clearly unfolding in the country at present).

Vulnerability to climate risk is also not only limited to rural producers and populations. Christensen and Stack (1992) examined regional and national surveys of food security and delineated several vulnerable groups including urban unemployed, informal workers; rural communal farmers; landless, commercial farm workers; urban unemployed and informal workers. By comparing 2 cases, one which represents a medium level of population growth and medium economic growth (business as usual IPCC approach) and a continuation in current trends of social vulnerability, a declining share of agriculture in GDP and rapid urbanization is suggested. The second case is more normative, maintaining economic growth but with a low population growth. Per capita income is over a third higher than in the first case and much gain is in the agricultural sector (Achebe et al., 1990; Christen and Stack, 1993; Downing, Watts and Bohle, 1996).

The issue of food security in southern Africa, as shown here, is directly linked to climate change and variability. Recurrent droughts and floods have made farming, for both small and large-scale producers, a ‘risky’ operation with significant outcomes for livelihoods. Climate change scenarios have been presented, illustrating that shifts may occur in wetter and drier areas. Maize production impacts have also been traced here and elsewhere in this report. The physical environment is, however, only one determinant in shaping food security. Issues such as access to food also have to be considered. Here factors such as socio-political developments in the region, the role of HIV/AIDS and population dislocation may exacerbate vulnerabilities initially framed by climate variations. Having described some of the environmental factors predisposing people to heightened vulnerability and risk, attention finally turns to some suggestions for mitigation of such risks.

PART III — SUGGESTED WAYS TO MITIGATE RISKS IN A CHANGING ENVIRONMENT

Various options can be considered to enhance resilience when faced with some of the risks associated with changing environments as identified above. Using a livelihoods approach, some argue for greater diversification in livelihoods (e.g. Bryson, 2000). By promoting strategies that may improve livelihoods in all its dimensions (e.g. promote human capital, continue to search for low-cost ways of enhancing agricultural productivity and other risk-reduction strategies) households and communities may be better able to live through periods of abrupt change. Enhancing resilience, through a variety of mechanisms, such as diversification (e.g. Bryson, 2000) therefore need to be considered.

Some more practical suggestions for mitigation include those for water and agricultural activities including for example: repairing water pumps, deepening wells, harvesting rain water, establishing rules for local water usage in a community. Agricultural examples may include planting early, increasing the area of smaller grains, procuring drought tolerant seeds, collective hiring of farm resources e.g. tractors (von Kotze and Holloway, 1999).

These activities, it must be noted, should not be 'emergency type actions, but should be part of on going, every day, 'development' activities

Increased science and improved attention to usable science are also needed. Effective water management strategies, for example, will depend on long-term, reliable data for a particular region including good biophysical and socio-economic data and monitoring, improved early warning systems and accessibility of information etc. The examination of the role of globalisation, structural adjustment policies (e.g. Benson and Clay, 1998) and various initiatives (e.g. NEPAD) and how these impact on 'life' on the ground are also required. For example, are water supplies and infrastructure affordable in various areas, who manages these resources and what form of ownership is in place to ensure the 'sustainability' of such resources? Overall integration of various development programs and policies should also ensure that mitigation is undertaken (e.g. linking water, environmental and 'disaster' management programmes).

Several suggestions have been made to possibly mitigate the impacts of HIV on families and the wider environment e.g. including calls for greater integration and cooperation between the health and agricultural departments in various countries, increasing the understanding of the multi-sectoral impacts of HIV and the environment; integrated community-based programmes and labour-saving technologies (e.g. efficient use of farm waste), use of mobile livestock enclosures and the improved understanding of the agro biodiversity in rural areas that can be used to mitigate growing food insecurity associated with rising AIDS illness and fatalities (e.g. home gardens, wild food plants, medicinal plants, indigenous agro ecological knowledge and practice and community seed systems) (Gari, 2002).

CONCLUSIONS

In this report, and as per the brief provided, an attempt has been made to trace some of the environmental vulnerabilities in the region, particularly in the face of changes wrought by climate, HIV/AIDS, varying institutional capacity and conflict and refugee movements. One of the central problems in writing this report has been the need to weigh scientific reasoning against the moral concern of those working as humanitarian agents in the region. The need for greater certainty and precision of future assessments and scenarios, a useful tool for those trying to alleviate chronic food shortages in the region and reduce future risks, has to be tempered with the current, available rigor of these models used to drive the scenarios of future vulnerability in the region. The overwhelming need for reliable and better science in the face of growing emergencies and concerns, has been, and is an ongoing dilemma. It is hoped that this report, raises some of the key issues for further analysis and points to some useful contacts and papers that may assist in future work.

Notwithstanding some of these concerns, environmental vulnerability in the SADC region has been traced. Potential increases in aridity and decreases in rainfall have been indicated for some areas of the region, with resultant changes in hydrological regimes. Impacts on agriculture and food security have been outlined with an important note that changes in rainfall and temperature may be offset by changes in CO_2 that may temper some of these climate changes (favouring tree growth, enhanced yield in maize). The role of HIV/AIDS and migration was also discussed and here the uncertainty in the future is also difficult to call.

With all these issues in mind, the need for better adaptation and enhanced resilience both NOW and in the future is clear, particularly for improved quality of life for those most at risk in the region e.g. children. Trying to improve local understanding of biophysical vulnerability and how this may be enhanced/diminished by various activities remains key for those working in the region. The risks of future climate variability and other hazards, may not, however, be the most pressing problem for many in the region. There is therefore, the need to adopt realistic approaches in a changing environmental setting.

One way to enhance livelihoods, both now and in the future, is through diversification and finding ways for better spreading of risk. Some have called for such moves both in the region and elsewhere in Africa. The future of many in the region, it is argued by some, lies in labour-force participation outside of rural agriculture (Bryson, 2001). In the longer term, Devereux (2000b) also calls for "support to diversification away from precarious livelihood systems (agriculture and pastoralism) towards sustainable alternatives whose returns are not correlated with rainfall" (Devereux, 2000b, 14). Capability enhancement through human capital therefore seems vital (including literary, numeracy, and other skills, see Bryson, 2000). Such enhancement of human capital may help people to develop resilience to external shocks and stresses as highlighted in this report. This, however, will require institutional support at various levels and moreover the political will.

The one overwhelming requirement, after all is presented, remains, is 'political will'. As de Waal (1997, 105 and cited in Devereux, 2000a), highlights in work in the Sudan: "There have been technical advances, but these have been largely meaningless without political commitment (in this case to fight famine)”. Deveruex (2000a) continues:

> “What is uncontroversial is that the capacity to feed the world is not enough. Political will is also needed. As the balance of famine causality shifted decisively from ‘natural’ factors, so the responsibility for both creating and preventing famines became intensely politicised…It is the urgent responsibility of the present generation of national and international policymakers to translate one of the most remarkable achievements of the 20th century—the potential to guarantee food security, the right to freedom from hunger for all the world’s population (particularly for children and the elderly)—into a 21st century reality” (Devereux, 2000, 29, parentheses added by Vogel).

SELECTED REFERENCES

Web sources:

www.sadc-fanr.org.zw: Regional Flood Watch, 25 January, 2002; SADC Food Security Bulletin.

www.wmo.ch: WMO (World Meteorological Organization) statement on the status of the global climate in 2001.

www.cru.uea.ac.uk: 2001: Second warmest year globally since records began.

www.scidev.net: Paper by Mike Hulme and Simon Torok: The scientific evidence for human-induced climate change.

http://iri.columbia.edu/ENSO/index: International Research Institute for Climate Prediction.

www.sadc-fanr.org/rfw/jan252002: Regional Flood Watch, 25 January, 2002.

www.undp.org/hiv/publications: UNDP publications on HIV/AIDS

www.nbi.ac.za: (National Botanical Institute, Cape Town). See also their popular version of bio climate modelling and plant diversity impacts etc, "The Heat is On").

Personal Communications

Dr B. Scholes, Enviromintek, CSIR.

Dr Simon Mason, Climate Research Division, Scripps Institution of Oceanography, La Jolla, California (smason@ucsd.edu).

Ass. Prof. Bruce Hewitson, Climate Systems Analysis Group, Department of Environment and Geographical Sciences, University of Cape Town.

Selected Books And Papers

Achebe, C., Okeyo, A.P., Hyden, G. and Magada, C.H.D. (eds)., (1990): *Beyond Hunger in Africa*, Heinemann, Nairobi.

Barnston, G.A., Glantz, M.H. and He, Y., 1999: Predictive skill of statistical and dynamical climate models in SST forecasts during the 1997-98 El Niño episode and the 1998 La Niña onset, *Bulletin of the American Meteorological Society*, 80, 217-243.

Benson, C. and Clay, E., 1998: The Impact of Drought on Sub-Saharan African Economies, *World Bank Technical Paper 401*, World Bank, Washington.

Bridgman, H.A., 1998: Future climates for the southern continents, Chapter 9, In: Eds, J.E. Hobbs, J.A. Lindesay and H. A. Bridgman (eds), *Climates of the Southern Continents, Present, Past and Future*, Wiley and Sons, New York.

Bryson, D., 2000: Rural Africa and the crossroads: Livelihood practices and policies, *ODI Natural Resources Perspectives, No. 52*., ODI.

Buckland, R.W., 1994: The implications of climate variability for food security in the Southern African development Community (SADC) from the lessons learned from the 1991-92 Southern African Drought, in: Glantz, M. (ed), Usable Science: Food Security, Early Warning and El Niño, Workshop Proceedings, 25-28October, 1993, Budapest, Hungary, 185-194.

Cambula, P., 1999: Impacts of climate change on water resources in Mozambique. Republic of Mozambique, *Final report of the Mozambique/U.S. Country Study program Assessment of the Vulnerability of the Economy of Mozambique to projected Climate Change*, Maputo, Mozambique (unpublished).

Cane, M., 2000: Understanding and predicting the climate system, In: Hammer, G.L., N. Nicholls and C. Mitchell (eds), *Application of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems*, Kluwer Academic Publishers, 29-50.

Christensen, G. and Thomas, D., 1993: Policy analysis for household food security case study: Rural Zimbabwe, Working Paper No. 7, Food Studies Group, Oxford.

Crush, J., 1997: Covert Operations: Clandestine Migration, Temporary Work and Immigration Policy in South Africa, SAMP Migration Policy Series, No. 1, Idasa, Cape Town.

Davies, S., 1995: *Adaptable Livelihoods: Coping with Food Insecurity in the Malian Sahel*, Basingstoke, Macmillan.

Davies, B., 1997: Monday Paper, Sustainable Use of Cahora Bassa Dam, Vol 16., 20, July – August, 1997, www.uct.ac.za/depts/dpa/monpaper/97.

de Waal, A., 1989: *Famine that Kills: Darfur, Sudan, 1984-1985*, Oxford, Clarendon Press.

de Waal, A., 1997: *Famine Crimes: Politics and the Disaster Relief Industry in Africa*, Oxford, James Currey.

Devereux, S., 2000a: Famine in the Twentieth Century, IDS Working Paper 105, Sussex.

Devereux, S., 2000b: Food Insecurity in Ethiopia, a discussion paper for DFID, October 2000.

Downing, T., Watts, M. and Bohle, H., 1996: Climate change and food insecurity: Towards a sociology and geography of vulnerability, In: Downing, T. (ed), *Climate Change and World Food Security*, North Atlantic Treaty Organisation ASI Series, Volume 137, Springer-Verlag, Berlin and Heidelberg, Germany, 183-206.

Du Guerny, J., 1999: AIDS and agriculture in Africa: can agricultural policy make a difference? FNA/ANA 25 1999, link to web site of FAO thru www.undp.org/hiv/publications

Du Toit, A.S., M.A. Prinsloo, W. Durand, and Kiker, G., 2000: Vulnerability of maize production to climate change and adaptation assessment in South Africa, Country Studies, 2000.

Engh, I., Stloukal, L. and du Guerny, J., 2000: HIV/AIDS in Namibia: The impact on the livestock sector, www.fao.org/waicent/faoinfo/susdev.

FEWSNET and SCF, UK., 2001: *Southern Africa Humanitarian Update, 1 March, 2002*.

Gari, J.A., 2002: Agrobiodiversity, food security and HIV/AIDS mitigation in Sub-Saharan Africa, www.fao.org/waicent/faoinfo/susdev.

Glantz, M.H., 2001: *Once Burned, Twice Shy? Lessons learned from the 1997-98 El Niño,, Reducing the impact of environmental emergencies through early warning and preparedness: the case of the 1997-98 El Nino*, UNEP, NCAR, National Center for Atmospheric Research, United Nations University UNU, WMO and ISDR (International Strategy for Disaster Reduction).

Goddard, L., Mason, S.J., Zebiak, S.E., Ropelewski, C.F., Basher, R. and Cane, M.A., 2001: Current approaches to seasonal-to-interannual climate predictions, *International Journal of Climatology*, 1111-1152.

Homer-Dixon, T.F., 1994: Environmental scarcities and violent conflict: evidence from case studies, *International Security*, 19, 5-40.

Hulme, M., (editor) 1996: Climate Change and southern Africa: an exploration of some potential impacts and implications in the SADC region, a report commissioned by WWF International and Co-ordinated by the Climate Research Unit, UEA, Norwich, U.K.

Hulme, M., 2000: Global Warming, *Progress in Physical Geography*, 24, 591-599.

IPCC (Intergovernmental Panel on Climate Change), 1998: The Regional Impacts of Climate Change, An assessment of vulnerability, chapter on Africa.

IPCC (Intergovernmental Panel on Climate Change), 2001: *Climate Change 2001: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press.

Joubert, A. and Tyson, P., 1996: Equilibrium and fully coupled GCM simulations of future southern African climates, *South African Journal of Science*, 92, 471-484.

Joubert, A. and Hewitson, B., (1997): Simulating present and future climates over Southern Africa using General Circulation Models, *Progress in Physical Geography*, 21, 41-78.

Landman, W.A. and Mason, S.J., 1999: Change in the association between Indian Ocean sea-surface temperatures and South African summer rainfall, International Journal of Climatology, 19, 1477-1492.

Landsea, C.W. and Knaff, J.A. (2000) How much skill was there in forecasting the very strong 1997-98 El Niño?, *Bulletin of the American Meteorological Society*, 81, 9, 2107-2119.

Lomborg, B., 2001, *The Skeptical Environmentalist, measuring the real state of the world*, Cambridge University Press.

Lowenson, R. and Whiteside, A., 2001: *HIV/AIDS Implications for Poverty Reduction*, Background paper prepared for the United Nations Development Programme for the UN General Assembly, Special session on HIV/AIDS, 25-27 June, 2001.

Macdonald, D., 1999: Lest the Rhetoric Begin: Migration, Population and Environment in Southern Africa, *GeoForum*, 30, 13-25.

Magadza, C.H.D., 1996: Climate change: Some likely multiple impacts in southern Africa, In: Downing, T. (ed), *Climate Change and World Food Security*, North Atlantic Treaty Organisation ASI Series, Volume 137, Springer-Verlag, Berlin and Heidelberg, Germany, 449-484.

Makhado, J.M., 1996: Potential effects of climate change on corn production in Zimbabwe, *Climate Research*, 6, 147-151.

Mason, S., 2001: El Niño, climate change, and southern African climate, *Environmetrics*, 12, 327-345.

Mason, S.J. and Goddard, L., 2001: Probabilistic precipitation anomalies associated with ENSO, *Bulletin of the American Meteorological Society*, 82, 619-638.

Mason, S. and Joubert, A., 1997: Simulated changes in extreme rainfall over southern Africa, *International Journal of Climatology*, 17, 291-301.

Matarira, C.H. et al., 1995: Vulnerability and Adaptation Assessment for Zimbabwe, US Country Studies (see also UNEP Framework for Climate Change, Country Studies on the web).

Meigh. J.R., Mckenzie, A.A., Austin, B.N., Bradford, R.B. and Reynard, N.S. (1998): Assessment of Global Water resources – Phase II. *Estimates for Present and Future Water Availability for Eastern and Southern Africa, DFID Report 98/4*, Institute of Hydrology, Wallingford, Oxon.

Millennium Ecosystem Assessment, Southern African Millennium Ecosystem Assessment (SafMA, 2002), Nature serving the people: a pilot assessment of Southern African Ecosystems).

Minaar, A. and Hough, M., 1996: *Who Goes There: Perspectives on Clandestine Migration and Illegal Alliens in Southern Africa*, HSRC, Pretoria.

Muchena, P., 1994: Implications of climate change for maize yields in Zimbabwe, In: C. Rozenweig, C., Iglesias, A. (eds), *Implications of Climate Change for International Agriculture*, US Environmental protection Agency, Washington DC, 1-9.

Perks, L.A., Schulze, R., Kiker, G. and Horan, M. and Maharaj, M., 2000: Preparation of

data and information for application in impact studies of Climate Change over Southern Africa, Report to S.A. Country Studies for Climate Change Programme, ACRUcons Report 32., Pietermaritzburg, Natal.

Rozensweig, C. and Hillel, D., 1998: *Climate Change and the Global Harvest, Potential Impacts of the Greenhouse Effect on Agriculture*, Oxford University Press, New York.

SADC, 2000/2001: Annual Progress Report, The Water Sector….see also Health and other available reports, Information Officer, pndeble@sadc.int).

Save the Children Fund and Farm Community Trust of Zimbabwe, 2001: Rapid Household Economy Assessment of Chihwiti and Gambuli Informal Settlements, Makonde District, Mashonaland West, Zimbabwe, 25-28th September, 2001.

Save the Children Fund, 2001: Regional HIV Framework, Save the Children UK, West and Southern Africa.

SARDC, IUCN and SADC, 1994: State of the Environment in Southern Africa. SARDC, IUCN and SADC, Harare, Zimbabwe and Maseru, Lesotho (cited in the Global Environmental Outlook, UNEP).

Sen, A., 1981: *Poverty and Famines*, Oxford, Clarendon Press.

Shackelton, L.Y., Lennon, S.J. and Tosen, G.R., 1996: *Global Climate Change and South Africa*, Environmental Scientific Association, Cleveland, 160 pp.

Scholes, R. J. and van der Merwe, M.R., 1996: Sequestration of carbon in savannahs and woodland, *The Environmental Professional*, 18, 96-103.

Scholes, R.J., Midgley, G.F. and Wand, S.J.E., 2000: The vulnerability and adaptation of rangelands in South African Climate Change, Country Studies.

Sharma, N., Damhang, T., Gilgan-Hunt, E., Grey, D., Okaru, V and D. Rothberg, 1996: *African Water Resources: Challenges and Opportunities for Sustainable Development*, World Bank Technical Paper, NO. 33, African Technical Department Series, The World Bank, Washington DC, USA, 115 pp.

Schulze, R., (1990) Climate change and hydrological response in southern Africa: heading towards the future, *South African Journal of Science*, 86, 373-81.

Schulze, R., 1991: Global climate change and hydrological response: a southern African perspective. In *Proceedings, fifth South African national hydrological symposium*, Cape Town, NSI, 1-1 to 1-17.

Schulze, R., Kiker, G. and R.P. Kunz, 1996: Global climate change and agricultural productivity in Southern Africa: through for food and food for thought, In: Downing, T. (ed.), *Climate Change and World Food Security*, North Atlantic Treaty Organisation ASI Series, Volume 137, Springer-Verlag, Berlin and Heidelberg, Germany, 421-447.

Schulze, R., 1997: Impacts of global climate change in a hydrologically vulnerable region: challenges to South African hydrologists, *Progress in Physical Geography,* 27, 1, 113-136.

Schulze, R., Meigh, J. and Horan, M. (2001) Present and potential future vulnerability of eastern and southern Africa's hydrology and water resources, *South African Journal of Science*, 97, 150-160.

Von Kotze, A. and Holloway, A., 1999: *Living with drought, drought mitigation for sustainable livelihoods*, David Philip, Cape Town and Intermediate Technology Publications, London.

Appendix 1: CLIMATE INFORMATION

As taken from the web:

STATEMENT FROM THE FIFTH SOUTHERN AFRICA MIDSEASON CORRECTION FORECAST MEETING OF THE SOUTHERN AFRICA CLIMATE OUTLOOK FORUM
20-21 December 2001, Harare, Zimbabwe.

JANUARY TO MARCH 2002 SEASONAL RAINFALL OUTLOOK UPDATE

SUMMARY

Most of the Southern Africa Development Community (SADC) region will experience a largely normal to above-normal rainfall for the period January to March (JFM) 2002.

This Outlook is relevant only for seasonal time scales and relatively large areas. Local and month-to-month variations may occur. Any changes in the projected patterns of sea surface temperatures (SSTs) and other indicators over the next few weeks would affect the outlook in some areas. Updates of the outlooks therefore will be provided by the Drought Monitoring Centre, Harare (DMCH) and the National Meteorological Services (NMSs) in their respective countries.

The users are strongly advised to contact their NMSs for interpretation of this Outlook, finer details, updates and additional guidance.

THE CLIMATE OUTLOOK FORUM

From 20 to 21 December 2001, the Fifth Midseason Correction Forecast Meeting of the Southern Africa Climate Outlook Forum was convened in Harare, Zimbabwe by the DMCH in conjunction with the Department of the Meteorological Services of Zimbabwe to formulate consensus guidance projected for January to March 2002 rainfall for the SADC region. Users were active participants in the forum and raised issues pertaining to the interpretation and dissemination of the seasonal outlook.

METHODOLOGY

The Forum reviewed the state of the global ocean-atmosphere system and its implications for this region. The principal factor taken into account was the current state of the near normal sea surface temperatures (SSTs) over much of the tropical Indian and Atlantic Oceans. The near average SSTs are expected to remain largely normal during the next three months although the SSTs in the eastern tropical Pacific are likely to slide into warmer-than-normal conditions towards the end of the period. Coupled global ocean-atmosphere models, physically based statistical models and expert interpretation were used in the development of the outlook. The current status of seasonal forecasting methodologies allows prediction of spatial and temporal averages, and may not fully resolve all factors that influence regional, national and local climate variability.

The experts established probability distributions to indicate the likelihood of above-normal, normal or below-normal rainfall for each zone (see Map). Above-normal rainfall is defined as within the wettest 33.3% of recorded rainfall amounts in each zone; normal is defined as the middle 33.3% of the amounts while below-normal rainfall is the driest 33.3% of the recorded rainfall amounts.

January-March 2002 period:

Zone I: (Seychelles) Likelihood of normal rainfall

Zone II (Mauritius) Normal to above-normal rainfall

Zone III: (Northern sector of Tanzania) Above-normal to normal rainfall

Zone IV: (Northern half of DRC and extreme northwestern Angola) Normal to above –normal Rainfall

Z***one V*** (Western and southern Tanzania, northern Mozambique, northern Zambia, northern half of Malawi, greater portion of southern DRC as well as central and eastern Angola) Likelihood of normal to above-normal rainfall.

Zone VI: (Southwestern Angola and northwestern Namibia) Rainfall is expected to be in the above-normal to normal range.

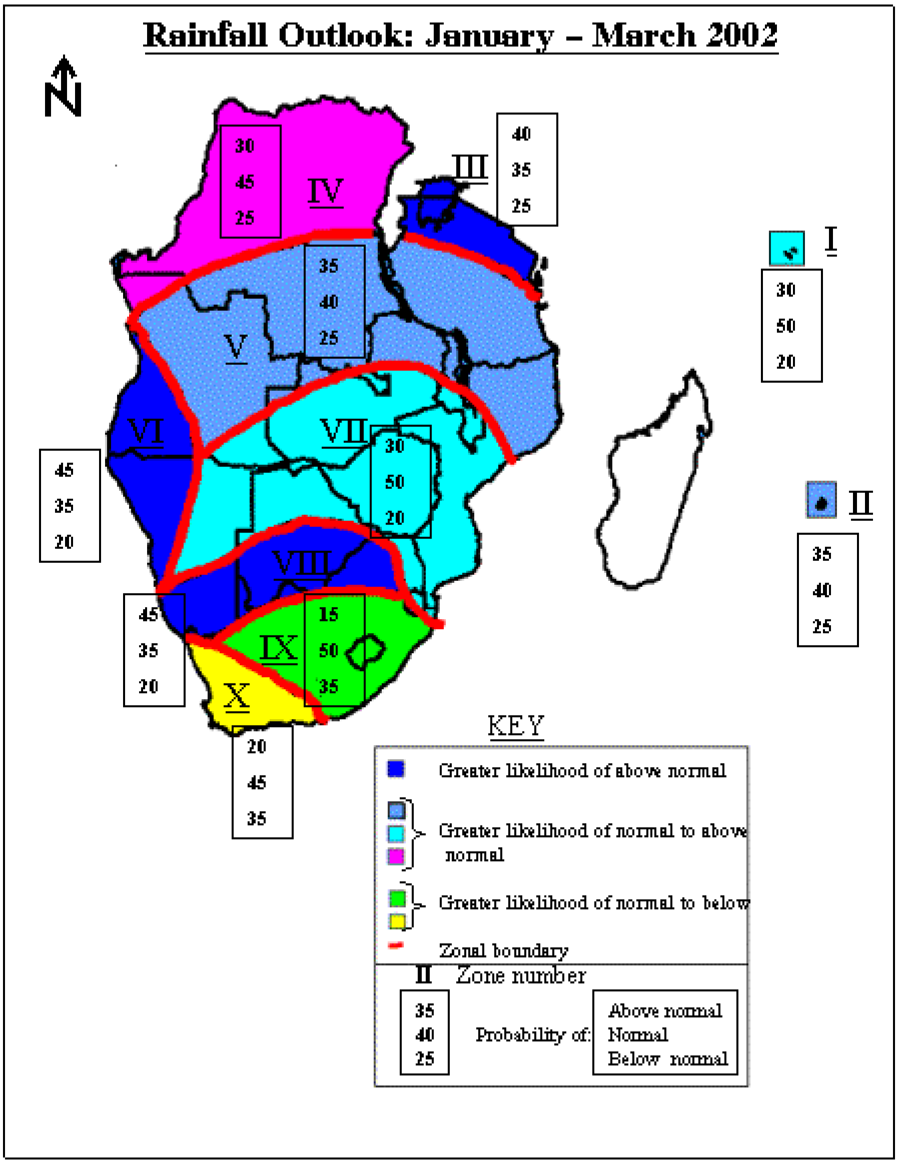
Zone VII (Northern Botswana, eastern half of Swaziland, Zimbabwe, southeastern Angola, southern tip of the DRC, central and northeastern of Namibia, southern half of Malawi, central and southern Mozambique, extreme eastern South Africa and southern half of Zambia) Likelihood of normal.

Zone VIII (Southern Namibia, southern half of Botswana, northernmost sections of South Africa) Likelihood of above normal to normal.

Zone IX (Most of South Africa, Lesotho and western Swaziland) Normal to below normal.

Zone X (Southwestern parts of South Africa) Normal to below normal.

These zones are shown on the attached Rainfall Outlook Map of JFM 2002.



The numbers for each zone indicate the probabilities of rainfall in each of the three categories: above-normal, normal and below-normal. The top number indicates the probability of rainfall occurring in the above-normal category, the middle number for the normal and the bottom for the below-normal. For example, Mauritius, (Zone II) there is a 35% probability for rainfall occurring in the above-normal category; a 40% probability for rainfall in the normal category and a 25% probability for a below-normal category. It is emphasized that boundaries between zones should be considered as transition zones.

CONTRIBUTORS

The Fifth Midseason Correction Forecast Meeting of the Southern Africa Climate Outlook Forum was convened in Harare, Zimbabwe 20 – 21 December 2001, by Drought Monitoring Centre-Harare (DMCH) in conjunction with Department of the Meteorological Services of Zimbabwe. Contributors to this consensus forecast included representatives of Meteorological Services from the following Southern African Development Community (SADC) countries: Botswana, Democratic Republic of Congo, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South

Africa, Swaziland, United Republic of Tanzania, Zambia and Zimbabwe. There were also climate scientists and other experts from SADC. Additional input was supplied by the International Research Institute (IRI), UK MET Office and European Centre for Medium Range Weather Forecasting (ECMWF). Users who participated in the deliberations of the forum contributed greatly in the final production of the statement.

Source:

Preliminary assessments from the Millennium Ecosystem Assessment, Southern African Millennium Ecosystem Assessment (SafMA, 2002), Nature serving the people: a pilot assessment of Southern African Ecosystems). Figures illustrate estimated cereal, water and biofuel availability and demand in the region (*awaiting permission to use figures*).

Figure 2 below: Cereal availability assessment (SafMA, 2002).