CLIMATE CHANGE

VULNERABILITY & ADAPTATION

ASSESSMENT

NAMIBIA

Final Report

March 2008

Developed by

Desert Research Foundation of Namibia
&
Climate Systems Analysis Group

for the Ministry of Environment and Tourism

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Regional node for climate modeling

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**Erik Dirkx, Claus Hager, Mark Tadross,
Shirley Bethune and Barbara Curtis**

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Last but not least we would like to express our appreciation for UNDP Namibia and MET who made this assessment possible and gave valuable guidance both in the run-up of the study and through the reviews.

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Acronyms and abbreviations

AIACC	Assessment of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors
AR4	Fourth Assessment Report (of the IPCC)
ARC	Antecedent Run-off Coefficient
CBNRM	Community Based Natural Resource Management
CBS	Central Bureau of Statistics
CDM	Clean Development Mechanism
CIFE	Commercial irrigation farming enterprise
CIMMYT	International Maize and Wheat Improvement Center
CSAG	Climate System Analysis Group
DART	Directorate of Agricultural Research and Training
DEA	Directorate of Environmental Affairs
DRFN	Desert Research Foundation of Namibia
DSSAT	Decision Support System for Agro-technology Transfer
DVS	Directorate of Veterinary Services
DWA	Directorate of Water Affairs
ENSO	El Nino Southern Oscillation
FAO	Food and Agricultural Organization of the United Nation
FIRM	Forum for integrated resource management
GCM	General Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GM	Genetically Modified
GRN	Government of the Republic of Namibia
GSA	Green Scheme Agency
HPI	Human Poverty Index
IFPRI	International Food Policy Research Institute
IIED	International Institute for Environment and Development
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
IWRM	Integrated Water Resource Management
LO	Initial Loss Factor
MAWF	Ministry of Agriculture, Water and Forestry
MET	Ministry of Environment and Tourism
Mm^3	Million Cubic Meter
NAB	Namibia Agronomic Board
NAMROM	Namibian Rainfall/Runoff Model
NAPCOD	Namibian Program to Combat Desertification
NCCC	Namibia Committee on Climate Change Commit
NCEP	

NDP	National Development Plan
NHIES	Namibia Household Income and Expenditure Survey
NPP	Net Primary Productivity
PPA	Participatory Poverty Assessment
PRS	Poverty Reduction Strategy
RCM	Regional Circulation Model
RoN	Republic of Namibia
SAM	Southern Annular Mode
SNC	Second National Communication
SSIF	Small-scale irrigation farmer
TAR	Third Assessment Report (of the IPCC)
TEP	Total Effective Precipitation
THI	Temperature-humidity index
TTT	Tropical Temperate Troughs
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
V&A	Vulnerability and Adaptation
WCE	Windhoek Consulting Engineers
WHO	World Health Organization

Executive summary

This Vulnerability and Adaptation assessment to climate change is carried out in preparation of the Second National Communication in meeting Government's obligations to the UNFCCC. The report addresses the vulnerability of the water and agricultural sectors to climate change, and suggest adaptation measures to cope with the expected impacts. Vulnerability is placed in the socio-economic contexts of rural areas, in particular the Karas and Caprivi regions.

Vulnerability and adaptation assessments, particularly at the local level, face limited knowledge about exactly what to adapt *to*. Namibia's natural variability only exacerbates the shortcomings of global and regional climate models which allow only for broad statements of change, and as such a first Namibia-specific modelling of climate change for the middle of the 21st century was undertaken. Alas, a lack of continuous data availability posed a serious constraint to both the climate models *per se* and all subsequent modelling of impacts on crop production and water run-off.

Namibian Climate

It is predicted with a high degree of certainty that Namibia will become hotter throughout the year (with a predicted increase in temperatures of between 1°C and 3,5°C in summer and 1°C to 4°C in winter in the period 2046 - 2065). Maximum temperatures have been getting hotter over the past 40 years, as observed in the frequency of days exceeding 35°C. Equally, the frequencies of days with temperatures below 5°C have been getting less, suggesting an overall warming.

Detecting trends in rainfall is typically more difficult, especially in highly variable arid climates such as Namibia. Considerable spatial heterogeneity in the trends has been observed, but it appears as if the northern and central regions of Namibia are experiencing a later onset and earlier cessation of rains, resulting in shorter seasons in most vicinities. There has been a statistically significant decrease in the number of consecutive wet days in various locations, and increases in measures of rainfall intensity could be observed. As far as predictions for the future are concerned, it is not obvious whether Namibian rainfall will be reduced, although intensity is likely to be increased. It is important to underscore that variability, and stronger variability at that, is likely to remain the key aspect of the Namibia's climate in the future.

Socio-economics and vulnerability

Vulnerability to environmental change not only depends on change in frequency or duration of climatic conditions, but also on the capacity to respond adequately to those changes. Household income, income diversification, availability of labour and the health status of household members are factors that determine vulnerability. The population of Namibia is expected to grow with 66% between 2001 and 2031 and this is expected to put pressure on land and water resources. Poverty, lack of income and lack of employment opportunities greatly exacerbate the vulnerability of households as these factors substantially constrain access to productive resources. In combination with environmental conditions and the impact of the HIV/AIDS pandemic, these factors constrain agricultural production and food security. Ultimately they contribute to limited adaptive capacity and vulnerability. External factors such as the existence of formal and informal social support networks, the availability and quality of health services, and prices of farm inputs and outputs further influence the capacity to cope with and recover from climate shocks, and are discussed further in the report.

The vulnerability to climate change differs for various socio-economic groups in Namibia, as the espective buffering capacity to deal with climatic shocks differs markedly. There are also considerable differences in vulnerability between regions. In his regard it should be noted that the impact of poverty and HIV/AIDS may reverse relatively favourable environmental conditions (i.e. Caprivi). In general, however, in a society where so many households are dependent on subsistence farming with constrained access to productive resources amongst the poorer segments of society, it is a matter of concern that the capacity for social organization and support in communities in various regions of the country appears to be dwindling.

Water sector

The role and importance of Namibian wetlands, and the expected impact of climate change on these is discussed. The projected warming in temperature result in evaporation and evapotranspiration increases in the range of 5-15%. Namibia has reached or exceeded its carrying capacity with regard to water in many areas of the county. The agricultural sector is the major user of water in Namibia; around 75 % of all water in the country is consumed by this sector. Commercial crop irrigation makes up for about 50% (~160 Mm^3) of national demand, and the Green Scheme is likely to add about another 80% (~290 Mm^3) above current irrigation abstraction.

A reduction of 10-20% in rainfall by 2045-2065 over the catchments of the Zambezi, Kavango, Cuvelai and Kunene rivers is expected to lead to a reduction in runoff and drainage in these river systems by +/- 25%. In addition the impacts on run-off, peak flows, and sustainable dam yields for the Fish river basin have been modelled. The interpretation of the results again is limited due to uncertainties in the models, particularly the climate models. Within these limitations, there are signs that runoff may increase in the far South of the country, whereas this is less clear for the central-southern area of Hardap. Dam yields are expected to be influenced by increased evaporation.

Wetlands are likely to provide reduced ecosystem services such as water retention, flood attenuation and water purification. The latter may again negatively affect rural livelihoods and tourism. The mouths of the Kunene and Orange rivers are likely to be affected, with possibly serious implications for their qualifications as Ramsar sites. Floodplains in the Caprivi and oshana's in the Cuvelai remain particularly vulnerable, as smaller areas will be inundated, and because they may dry out sooner due to increased evaporation. The Okavango delta may be strongly affected in similar ways, as a result of which it may potentially shift to a seasonal river.

With these ambiguities in changes in rainfall and runoff in Southern Africa in general and Namibia in particular, deducting the implications for groundwater recharge in specific regions of Namibia, such as the Caprivi, the southern regions and the Omaruru and Kuiseb, proved to be an exercise of very preliminary nature. Literature suggests that groundwater recharge may suffer a reduction of 30-70% across Namibia; a potential exception could be found in the recharge of alluvial aquifers that have their origins in central areas of Namibia, where more late summer convective rainfall can be expected by the mid of the 21st century (a trend that can moreover already be observed).

It is predicted, even without the additional stresses of climate change on the water resources, that demand will have surpassed the installed abstraction capacity by 2015. In terms of water resource management the combined impact of climate change, population growth and development imply that there needs to be continued attention for dealing with evaporation and thus for improving efficiency of the utilisation of water resources.

In view of added stress on water resources caused by climatic changes, it will become more important to carefully manage demand for water and to devise ways of storing water so that it is not subject to evaporation. In this regard Namibia could build on its vast experience with IWRM, conjunctive use of surface- and groundwater resources and recent experience with subterranean storage. Demand management concerns the management of domestic demand in municipalities, industrial or mining demand, as well as the agricultural sector.

Agricultural Sector

The agricultural sector is acknowledged as critical to the subsistence base of a large section of Namibia's society. The dualism of the sector, with its marked differences in access to credit, markets and inputs, accentuates the socio-economic vulnerabilities of rural dwellers in Namibia. The volatility of the production systems is highlighted by the national accounts, and the difficulty the sector experiences in living up to the expectations as a driver of the economy for Vision 2030 are clear to see.

In order to establish *what to adapt to* crop modelling was undertaken in collaboration with the MAWF. Potential yields and planting windows for the middle of the 21st century were modelled for Namibia's main staple grains; maize and pearl millet, for both Rundu and Grootfontein as proxies for major crop production sites. Unfortunately insufficient continuous meteorological data was available to model crop production for the important North-Central regions. The crop models remained largely inconclusive, presumably as uncertainties in the downscaled climate models are exacerbated through the modelling exercise. There is a tentative indication that the potential for crop production in the Grootfontein area might increase in lieu of predicted climate change.

Literature review of the impact of climate change on the livestock sector focused on grazing availability, quality, and bush encroachment; livestock production and reproduction; water availability and demand; and disease and parasite impact. Significant changes in vegetation structure and function are projected in several areas of Namibia due to climate change; the dominant vegetation type termed Grassy Savanna is projected to lose its spatial dominance to Desert and Arid Shrubland vegetation types, with projected increases in bush encroachment for the north-eastern parts of the country. Vegetation is projected to suffer some reduction in cover and reduced Net Primary Productivity (NPP) throughout much of the country. It appears as if thresholds for conception in cattle will be breached for some of the popular breeds in Namibia as average maximum temperatures will exceed 34°C for large parts of the hot season. The temperature increase is likely to increase water demand, thus reducing grazing distances and most likely exacerbating degradation around watering points. Warming, with concomitant changes in rainfall distribution in Namibia, could lead to changes in the spatial or temporal distributions of those diseases/vectors/pathogens sensitive to climate.

In the context of these climate change vulnerabilities and a projected population growth of 66% by 2031, the reliance of many rural households on subsistence agriculture, and the limited formal skills base offering a path into other sectors, constitutes a major challenge to both food security in rural households, and sustainable development in Namibia at large against a predicted decline of between 1,1% and 3,1% in Namibian GDP due to climate change losses.

Adaptation

Adaptation is the process to improve society's ability to cope with changes in climatic conditions across time- and policy scales. Following a brief review of agricultural policy in the context of climate change adaptive responses for the agricultural sector are structured along technical, policy and institutional topics, and include *inter alia* diversification options, management practices, improving the exercise of best technical options as well as the improving the characteristics of such available options, and communication and translation of information. The importance of addressing climate change from a developmental perspective, cutting across policies and warranting action *today* is highlighted.

Adaptation to climate change in the water sector should focus on dealing with the effects of increased evaporation. Hence it is important to enhance the efficiency of water use and to manage the supply and demand of water by means of the conjunctive use of water resources, including sub-surface water banking. Improvement of water demand management practices, especially addressing the effectiveness of water management in local authorities may go a long way to delay major water infrastructure investments. The Basin Management Approach may assist in raising awareness of the vulnerability to climate change amongst communities, but more resources and capacity building are required to gain experience with the approach. Responsibilities of basin management committees *vis a vis* large institutional stakeholders need to be clarified in order to ensure that water managers can address the challenges faced by climate variability and climate change.

In terms of managing the impacts of drought and floods the capacity for disaster risk preparedness, rather than disaster response, should be strengthened. Spatial planning that takes ecosystem requirements into consideration has the potential to markedly reduce flood related costs. Finally, in order to address the disaster-relate risks suffered by the majority of the rural population it is of utmost importance to look into the matter of developing pro-poor disaster insurance schemes.

Limitations of the study

The Vulnerability and Adaptation assessment was made difficult by the high level of uncertainty Namibia's natural variability poses for climate modelling (itself beleaguered by challenges), and subsequently for crop and run-off modelling. The diminishing availability of long-term primary data across Namibian weather stations necessitated vast interpolation of results which do not lend themselves to accurately project future changes.

There were drawbacks to the choice of employing crop and run-off modelling, which turned out to be very time-consuming and unfortunately hardly yielded conclusive results. On the other hand capacity for modelling has been built which, as the science improves, will be useful in future work.

Difficulty was experienced in narrowing down *what* to include in the report has led to an obviously lengthy report. Overall, the uncertainties in the very foundation of the arguments, i.e. the climate change models, surface throughout the report and detailed investigations will be needed to develop, over time, higher degrees of confidence in what the likely scenarios and consequences are.

Recommendations

This section comprises of lessons learnt in the implementation of this vulnerability and adaptation assessment, and highlights a selection of either structural adaptation suggestions or the more pressing adaptation measures Namibia should pursue to strengthen its national resilience to climate change. More detail and further options are presented in the adaptation chapter.

Policy

- In the face of the prevailing uncertainties in climate change *per se*, and the observed increase in variability of the Namibian climate, adaptation to climate change should be placed high on the national development agenda. Adaptation is a matter that should not be delayed, as an early start contributes to a reduction in the costs associated with adaptation. In connection to this it is also relevant to strongly support recent efforts to mainstream climate change in national development policy frameworks.
- Against the background of the highly variable climatic conditions and the risk of extreme events, it is important that policy be developed to safeguard the limited productive assets of rural Namibian's by means of targeted, **pro-poor disaster insurance schemes**. Apart from protecting productive resources of the rural population, policy should target the diversification of the rural economic environment and strengthen rural-urban linkages. These policy directions should receive adequate attention during the formulation of a **rural development policy and strategy**, which is currently lacking in Namibia's policy framework.
- A national debate to **clarify the expectations of the agricultural sector to national development**, also in lieu of climate change, should be initiated to streamline policies aimed at the sector. Outright conflicting goals prevail which further undermine the potential of this vulnerable sector as well as the sustainable use of the environment.
- **Support to renewable energies**, a sector in which Namibia is very well endowed, should be rendered. Against the background of climate variability and climate change, support to the fledging economic use of biomass (invader bush) is a priority. In addition, Namibia's capacity to benefit from the CDM needs to be developed.
- Namibia is a leader in Africa in experience of **conjunctive use and IWRM** principles. This capacity should be cherished and built upon for the national and African good. At the local level water harvesting and water use efficiency should be developed and promoted.
- In connection with recent trends in the **mining industry,** prevailing trends in **rural-urban migration** and scheduled expansion of **irrigated agriculture**, **demand for water** is expected to surpass installed abstraction capacity shortly after 2015. Such water stress calls for urgent steps in monitoring of groundwater levels across Namibia and in water demand management (WDM). The pace of urbanisation further requires the development of appropriate sanitation systems.
- Pricing mechanisms in the water, land and electricity sectors should **reflect the real scarcity of the goods**. Incentives and disincentives (including equitable or pro-poor pricing mechanisms and conservation tariffs) should be devised which prompt resource stewards to be prudent in resource use.

- There is an urgent need for the identification of **adaptation packages** which could address critical climate change challenges in the short, medium and long term. These packages would consider which combination of technological, behavioral, institutional and policy mechanisms would yield the biggest cumulative benefit.

Capacity

- In view of the extent of flood related damage currently experienced, the capacity to undertake **spatial planning,** including town and regional planning and engineering, should be strengthened to include ecosystem requirements (this would for instance avoid malls/roads in Oshana's without any storm-water provisions).
- Boundary organizations in Namibia should be strengthened to facilitate climate change feedback loops between science institutions, policy makers, and land users. This requires capacity to access, interpret, translate and communicate climate change science and concomitant local level indicators. **Communicating climate change** considerations is considered a particular challenge due to the complexity of the issues, as well as the diversity of target groups that need information (politicians, policy makers, and farmers).
- Capacity should be built (amongst academics and professionals) in Namibia to apply and interpret climate models and impact models in sectors that are considered critical for the development of Namibia, with the aim to build a broader understanding of the vulnerability of various sectors to climate variability and change. Such capacity building should further focus on the application of **economic principles** to quantify/compare the impacts of certain changes and policy interventions to **foster fact-based decision-making** when allocating very scarce public resources to certain adaptation programmes or interventions. This will require more in-depth analysis of certain sub-sectors in e.g. the agricultural sector.

Data

- There is a marked **paucity in readily available weather data** due to diminishing numbers of weather stations across the country taking continuous measurements.
- Climate, and in particular precipitation is very location-specific in semi-arid climates such as Namibia's. To obtain a better understanding of how rainfall patterns have evolved over the past century, meticulous screening of available data is required. It is furthermore important to fine-tune methods in climate research to allow for assessing the **inter- and intra-annual variability**. A more detailed analysis of local data will contribute to improved quality of climate and impact modelling in certain sectors, and is likely to further contribute to improved decision-making processes and disaster risk preparedness.
- The catchment areas of Namibia's critically important perennial rivers lie mostly across international borders, and **smooth exchange of data** is required with e.g. Angola and Zambia to improve the quality of impact modelling (rainfall-runoff relations) and to contribute to more informed policy decision-making processes in Namibia.
- In order to enhance disaster preparedness **vulnerability mapping,** both in a technical sense (using remote sensing techniques) and in a participatory manner, should be undertaken. Whilst the former will assist in delineating areas where scarce flood events could occur to assess where infrastructure could and could not be developed, the latter allows for the identification of adaptation strategies that are based on the needs and priorities of those living in disaster prone areas. It might also contribute to the revival of indigenous coping strategies.

Background to the study

Namibia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and became legally obligated to adopt and implement policies and measures designed to mitigate the effects of climate change and to adapt to such changes. The Global Environment Facility (GEF) through the United Nations Development Program (UNDP) approved funding for Namibia's proposal on its Second National Communication (SNC) to be presented to the United Nations Framework Convention on Climate Change (UNFCCC). The Ministry of Environment and Tourism (MET) through its Directorate of Environmental Affairs (DEA) is responsible for overseeing the coordination of Climate Change issues in Namibia thus the implementation of the SNC project in order to fulfil the country's obligations under the Convention. The SNC project activities will build on and continue the work done under the Initial National Communication (INC) and the top-up Enabling Activities Projects in which different components of the project were identified

The Initial National Communication (INC) of Namibia presented to the UNFCCC in 2002 reported that the Namibian economy is natural resource based and is extremely sensitive to climate change effects. The direct effects of climate change on the various economic sectors could potentially be felt in thematic areas such as water; agriculture; fisheries; ecosystems, biodiversity and tourism; coastal zone; health; and energy. More in-depth assessments however still needed to be carried out to provide detailed assessment on sectors such as agriculture and eco-system/biodiversity and tourism.

The NCCC, chaired by the MET, and with the support of the United Nations Development Program therefore called for an assessment of Namibia's vulnerability and adaptation processes to the expected impacts of climate change, awarding the contract to a consortium of the Desert Research Foundation of Namibia (DRFN) and the Climate Systems Analysis Group (CSAG) of the University of Cape Town. The primary focii of the vulnerability assessment for Namibia's SNC are the agricultural sector, rural development and the water sector.

Approach

The tasks involved in the V&A assessment requires information on how the climate of Namibia is expected to change in the future under anthropogenic climate change, quantified for either further impacts analyses e.g. crop and runoff modelling, or for assessing future potential vulnerabilities.

This report presents and assesses both the climate change data used for these analyses and the historical climate data, which provides the context for future change as well as suggesting where immediate efforts should be focussed. A major problem for this kind of assessment (and of any adaptation initiative, particularly at the local level) is the lack of knowledge about exactly what to adapt *to*. Whilst there are publicly available sources of information on climate change, much of it is regional (sub-continental in extent) and only allows for broad statements of change i.e. it is of limited use for making countrywide statements regarding change, let alone for specific regions within a country. Furthermore, for many sectors it is the combined effect of changes in rainfall and temperature that impact the sector; this necessitates the use of impact models such as crop models to investigate the combined effect on e.g. soil moisture and hence crop yield. Given these considerations it was therefore decided to undertake the following in addition to the climate modelling:

- Crop modelling for specific regions (undertaken in collaboration with the Department of Agriculture)
- Rainfall-runoff modelling for the Fish River Basin (undertaken by the Department of Water Affairs)

To accomplish these tasks projected climate data for the late 21st century was needed to run the crop and runoff models. The sources of such data are General Circulation Models (GCMs), which are commonly 'downscaled' to local scales for use in impact analyses, as they have limited applicability for regional assessments of change. More detailed information on the downscaling is presented in section 1.4.

Selection of regions and sites for various modelling exercises

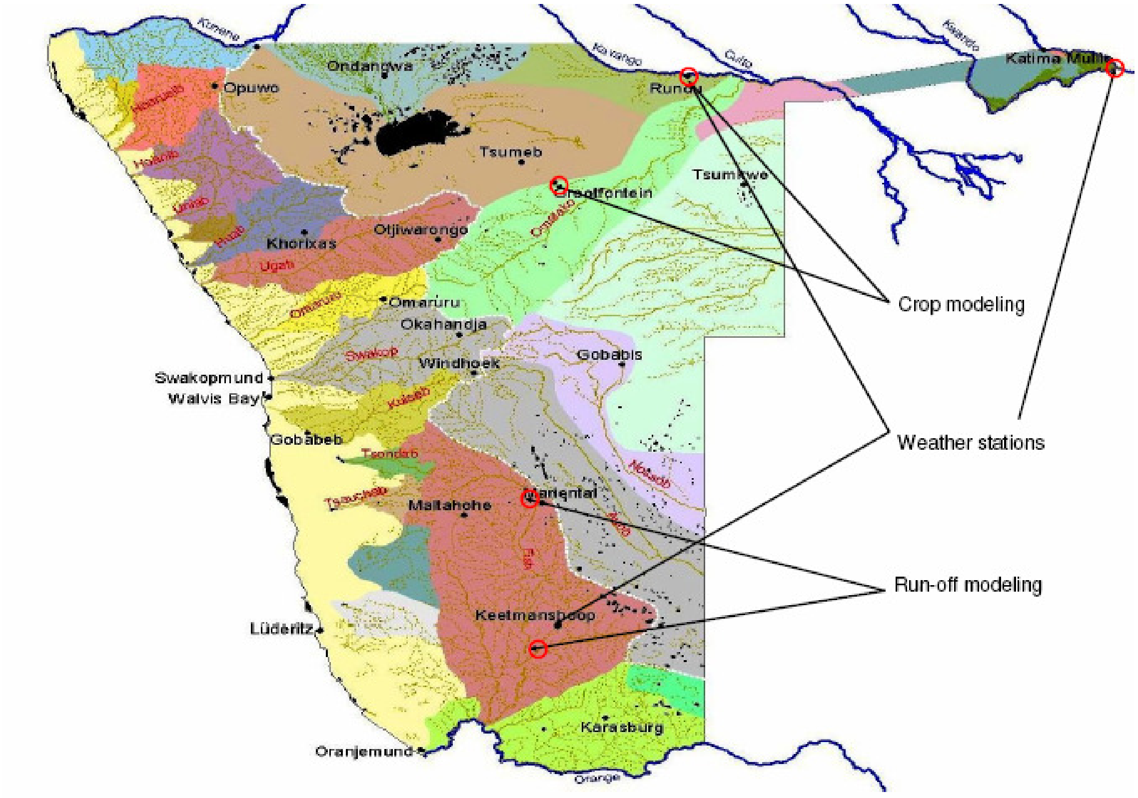
For this vulnerability and adaptation assessment attempts have been made to focus specific attention on the Caprivi and Karas regions, apart from presenting the climate change impacts and vulnerabilities for Namibia in general. The rationale for doing so is that these regions represent two extremes in Namibia in terms of geographical location, as well as environmental and socio-economic terms.

The analysis of historic trends in climate change and climate modelling were undertaken for the whole of Namibia. During the modelling process specific attention was however paid to three locations (Kazangula, Grootfontein and Keetmanshoop), so that predictions for temperature and rainfall could be analysed in more detail for a station in the Caprivi, a station in Karas and a third station in the middle of these two.

The crop modelling involved the modelling of potential yields and planting windows for the middle of the 21st century for Namibia's main staple grains, maize and pearl millet. As locations for the simulations Rundu and Grootfontein were selected as the best proxies for the major communal and commercial crop production sites, for which long term weather records were available. Unfortunately the paucity of meteorological records prohibited crop modelling for locations that are closer to the North-Central regions where cultivation of millet is carried out by a significant proportion of the population. Given the scope of the assessment the inclusion of Grootfontein further implied that a station in Caprivi could not be included.

The rainfall-runoff modelling was undertaken for two locations in the Fish River Basin in southern Namibia: Mariental and Keetmanshoop. The selection of these two towns was justified as they are located in the proximity of two major dams that supply the population in southern Namibia of water: the Naute dam in the Karas region and the Hardap dam in the Hardap region. Moreover, long term weather records could be obtained from the Meteorological Service of Namibia for these locations. Lack of input data prevented the undertaking of rainfall-runoff modelling for the rivers and floodplains in northern Namibia, i.e. the Caprivi.

Map of river basins in Namibia depicting sites selected for climate, crop and runoff modelling



Structure of report

The historical trends in climate change and the projected changes based on the statistically downscaled GCMs and RCMs are discussed in chapter 1. Chapter 2 presents the socio-economic context of vulnerability in Namibia with a special focus on the Caprivi, Karas and Hardap regions. Chapters 3 and 4 discuss the impacts and vulnerabilities to climate change for water resources and the agricultural sector in Namibia respectively. Chapter 5 presents suggestions for adaptation to climate change in Namibia. The annex includes a report on the analysis of rainfall-runoff modelling in the Fish River Basin undertaken in collaboration with the Department of Water Affairs.

1 Climate change in Namibia

The following section provides background information on the changes in historical climate observed over Namibia and the changes projected to occur towards the middle of the century, through anthropogenic climate change. As such it draws on observed data, reviewed literature and the 4th Intergovernmental Panel on Climate Change (IPCC) report (AR4).

1.1 Background

Namibia is one of the driest countries in southern Africa (mean rainfall ranging between 25mm and 700mm), largely because of it's proximity to the northward flowing Benguela current, which brings cold water to its western shores. This cold water is advected from the south and is partly driven by a high-pressure system over the South Atlantic (known as the South Atlantic anticyclone). The combination of cold water and high pressures leads to subsidence of cold dry air over much of Namibia, which generally suppresses rainfall. This situation is dominant during most of the year, except in summer when heating of the continent is greatest and the southerly position of the Inter Tropical Convergence Zone (ITCZ) draws moisture and rainfall from the tropics over northern and eastern Namibia. This situation results in a short rainfall season from November to April, the intensity of which is dependent on the flow of tropical moisture, which is in turn dependent on the positioning of tropical easterly waves and Tropical Temperate Troughs (TTT), which transport moisture to the south.

During winter mid-latitude storms pass to the southwest over South Africa. Whilst these systems generally pass to the south of Namibia, when in a northerly position they can bring rain to the southern parts of the country accounting for more than half the annual total. This rainfall may be enhanced in regions of steep topography. Fog constitutes another source of moisture in the cooler coastal regions where it may reduce visibility by as much as 146 days per annum. This moisture source is especially important to biota and desert plant species and it is not currently known how climate change will affect its intensity and distribution.

Occasionally during the autumn and more frequently spring seasons low-pressure systems, known as coastal lows, may develop over the west coast. These shallow systems propagate to the south and cause offshore airflow from the interior at their leading edge (promoting warm dry conditions) and onshore flow at the trailing edge (promoting colder conditions). Cut-off low-pressure systems are also found during these seasons and spin off from mid-latitude frontal storms to the south. These systems often move slowly and can result in heavy rains and flooding, especially if fed with moist tropical air from the north.

1.2 Global and regional climate trends

It is widely recognized that there has been a detectable rise in global temperature during the last 40 years and that this rise cannot be explained unless human activities are accounted for (IPCC 2001); (Solomon et al. 2007). The regional distribution of temperature increases is not however uniform and some regions have experienced greater change than others, especially the interior of continental regions such as southern Africa (see Figure 1.1). This is consistent with detected increases in annual temperatures found over southern Africa since 1900 (Hulme et al. 2001). Additionally these changes in temperature are associated with decreases in cold extremes with concomitant increases in hot extremes (New et al. 2006). Furthermore, the global average temperature indicates an increasing rate of change, such that temperature is rising quicker during the latter half of the 20th century (see Figure 1.1). Importantly, this increase in the rate of change is expected to continue, potentially resulting in more rapid changes of climate in the future.

Changes in rainfall are typically harder to detect due to greater variability, both in time and space. Even so, changing rainfall patterns are detected for many parts of the globe, including moderate decreases in annual rainfall over southern Africa. Where records are of sufficient length there have been detectable increases in the number of heavy rainfall events (Solomon et al. 2007) and within the southern hemisphere there is evidence for a moistening of the tropics and subtropics (Zhang et al. 2007). This is consistent with regional studies over southern Africa which have shown trends for an increasing length of the dry season and increases in average rainfall intensity (New et al. 2006). This has important implications for the seasonality of regional rainfall and together suggests a shorter but more intense rainfall season.

Besides changes in temperature and rainfall, other aspects of global change are notably (IPCC 2007):

- Increases in intensity and spatial extent of droughts since the mid-1970s;
- Decreases in northern hemisphere snowcover;
- Increases in the duration of heat waves during the latter half of the 20th century;
- Shrinking of the arctic sea ice pack since 1978;
- Widespread shrinking of glaciers, especially mountain glaciers in the tropics;
- Increases in upper-ocean (0-700m) heat content;
- Increases in sea level at a rate of 1.8 mm yr^{-1} between 1961 and 2003, with a faster rate of 3.1 mm yr^{-1} between 1993 and 2003.

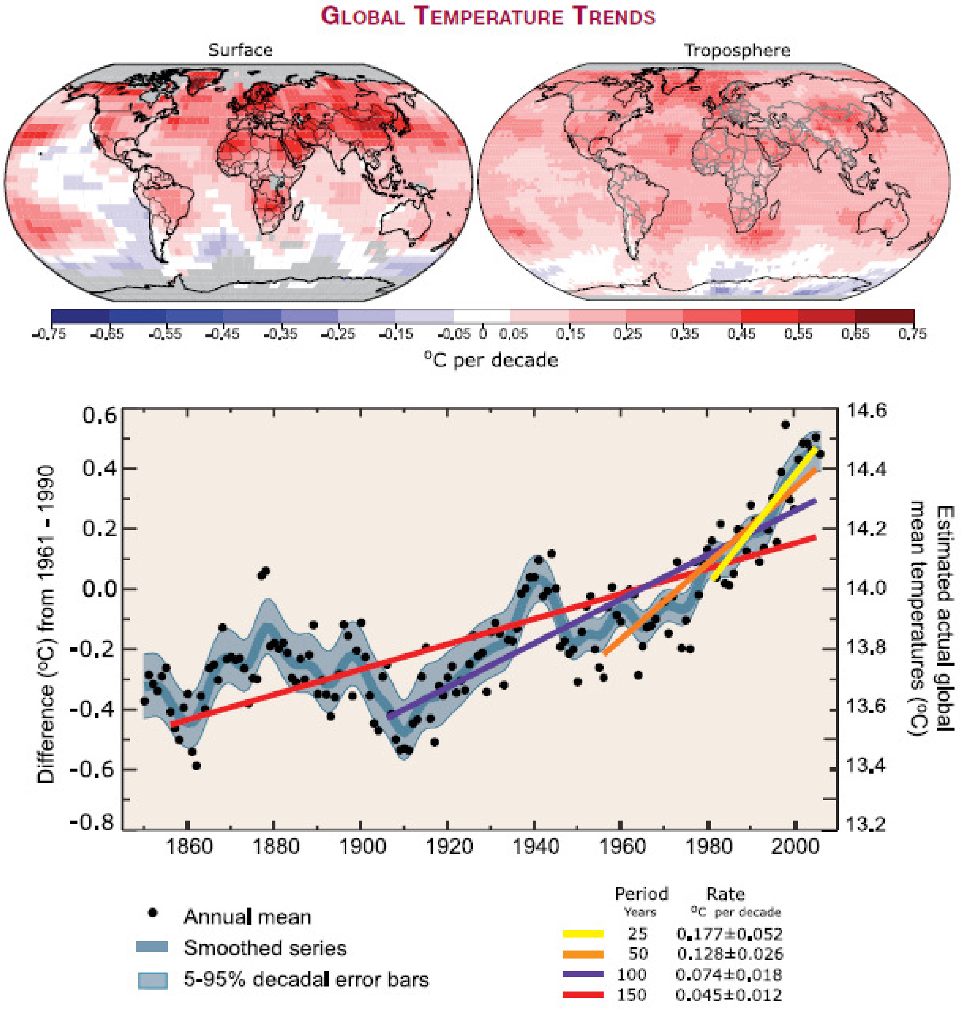
There is therefore compelling evidence for climate change at the global level, attribution to human activities, as well as it’s manifestation over southern Africa. However, understanding how global climate change may manifest itself at the country and local level is still a matter of research and is inherently linked to issues of uncertainty. So whilst the observed global level changes serve to highlight that climate change is a reality and that we have confidence in continuing and potentially accelerating change, it is necessary to explore how change is manifest at the country and local level.

1.2.1 Understanding uncertainty and risk

The issue of uncertainty is key to understanding past and future change and especially when designing adaptation strategies that will benefit both present and future socioeconomic situations. Uncertainty does not mean that we have no confidence in our projections of future climate. Indeed all climate projections, including seasonal forecasts, are couched in terms of probability of certain climate conditions appearing in the future. This is the framework within which humans often operate, allowing an assessment of future risks, e.g. consideration of financial and investment opportunities.

To be able to assess risk, one needs to consider all sources of information. It is therefore imperative that a probabilistic framework is used in developing projections which, at a minimum, should be an interpretive statement that draws on the diverse sources of information that are available. In this context and recognized within the IPCC process, one should recognize that four sources of uncertainty currently limit the detail of the regional projections:

Figure 1.1: **Distribution of global temperature trends (1979-2005) for the surface (left) and troposphere (right) from satellite records. Below: the average global temperature since 1850 indicating the increased rate of change during the later part of the 20th century. Source: (Solomon et al. 2007).**



- Natural variability. Due to the limiting factor of observations (both in time and space) we have a limited understanding of natural variability. It is difficult to characterize this variability and the degree to which it may exacerbate or mitigate the expected background change in climate. This variability itself may change due to anthropogenic factors, e.g. increases in the frequency of droughts and floods;
- Future emissions. Much of the future projected change, at least in terms of the magnitude of change, is dependent on how society will change future activity and emissions of greenhouse gases. Even so, the world is already committed to a degree of change based on past emissions (at least another 0.5°C warming in the global mean temperature). Society's response to managing emissions may result in a projected global mean temperature change of between 1.0° and 6.5°C by 2090-2099;

- Uncertainty in the science. This is complicated within Africa because current understanding of the regional dynamics of the climate system of the sub-continent is limited. There may be aspects of the regional climate system, which could interact with globally forced changes to either exacerbate or mitigate expected change e.g. land-use change. This could possibly lead to rapid nonlinear change, with unforeseen and sudden increases in regional impacts;
- Downscaling – the term used to define the development of regional scale projections of change from the global models (GCMs) used to simulate the global response of the climate system. The downscaling tools introduce uncertainty that limits the confidence in the magnitude of the projected change, although the pattern of change can be interpreted with greater certainty.

1.3 Recent historical trends of climate in Namibia

Studies of historical trends in climate over Namibia are limited (e.g. (Midgley et al. 2005); (New et al. 2006). Furthermore natural variability in such an arid environment is extremely high and is complicated by decadal variability. However, there is clear evidence that temperatures have followed the global trend, that there have been changes in atmospheric circulation and that the character of rainfall has changed appreciably. Whilst past trends are no guarantee of future change, especially in the context of uncertainty highlighted earlier, they are the foundation from which to assess current adaptation strategies to climate change and how they may be appropriate given future expected change. They also provide a context within which to understand the key processes that drive changes at the local scale.

1.3.1 Historical trends in air temperature in Namibia

Figure 1.2 indicates monthly surface air temperature observed over southern (figure 1.2a) and northern (figure 1.2b) Namibia. In both cases there is a clear trend for warmer temperature in the latter half of the 20th century, which is generally 1-1.2°C warmer than at the beginning of the century. It is notable that this warming is greater than the global mean temperature change, as noted by (Midgley et al. 2005), and an increase of 1°C.

There is also an indication that, similar to the global record, there was a peak in temperature during the 1940's, which cooled to a minimum in the mid 1970's. Global cooling during this period is mostly attributable to increases in volcanic and sulphate aerosols, after which the impact of anthropogenic emissions dominate the global temperature signal (IPCC 2007). This is evident in figure 1.2 as a rapid increase in temperature between 1975 and 2000, more so in the north of the country. Superposed on the positive temperature trends are decadal-scale fluctuations that suggest climate variability acting at these timescales and which are also seen in the rainfall record (see below).

Besides these general trends in temperature an analysis of 7 stations with more than 25 years of recent data (obtained from Meteorological Services of Namibia) indicates that there have been consistent increases in daily maximum temperatures across all stations, with both positive and negative changes in daily minimum temperatures (Table 1). Approximately 30% of the trends are significant at the 90% level or higher (noted in bold), most notably in the maximum values of daily maximum temperature suggesting that the most consistent change is that the hottest temperatures have been getting hotter. This can have potentially large negative effects on flora and fauna that are susceptible to high temperatures.

Table 1.1: **Trends (°C yr^{-1}) in annual maximum/minimim of daily maximum temperatures (Max T_{max} / Min T_{max}) and the annual maximum/minimum of daily minimum temperatures (Max T_{min} / Min T_{min}). Trends significant at the 90% significance level noted in bold.**

Station name	**Latitude**	**Longitude**	**Period**	**Max T_{max}**	**Min T_{max}**	**Max T_{min}**	**Min T_{min}**
Luderitz	-26.6333	15.1000	1960-2000	**0.075**	0.006	-0.013	0.032
Keetmanshoop	-26.5333	18.1167	1970-2006	**0.025**	0.016	**0.065**	**-0.042**
Windhoek	-22.5667	17.1000	1960-2006	**0.046**	0.007	0.02	0.01
Hosea Kutako Int. Airport	-22.4833	17.4667	1980-2006	0.005	0.024	0.024	-0.099
Sitrusdal	-21.4167	15.9333	1976-2003	**0.041**	**0.115**	**-0.053**	**-0.154**
Grootfontein	-19.9333	16.3833	1980-2006	0.085	**0.175**	0.136	0.055
Okaukuejo	-19.1833	15.9167	1975-2004	0.03	0.025	0.027	0.013

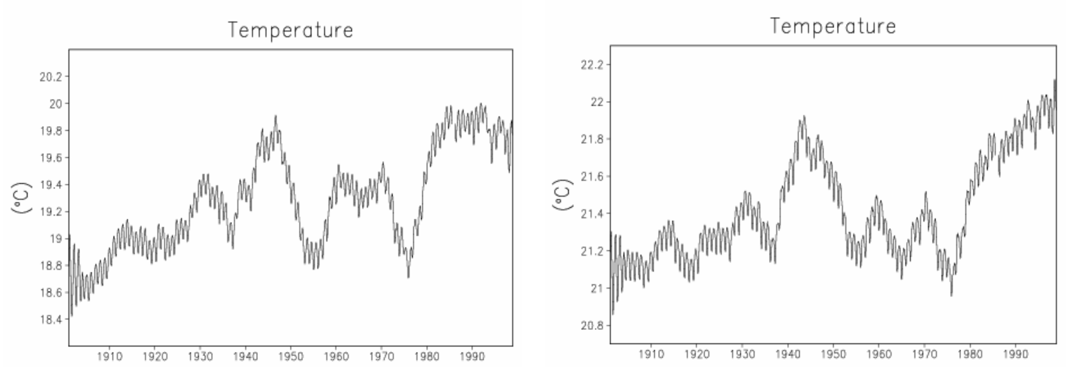
Besides these increases in minimum and maximum temperatures there have been statistically significant increases in the frequency of days with maximum temperatures above 25°C (Hosea Kutako, Keetmanshoop, Sitrusdal and Windhoek) and 35°C (Keetmanshoop, Sitrusdal and Windhoek), with decreases in the frequency of days with minimum temperatures below 5°C (Hosea Kutako, Keetmanshoop, Okaukuejo and Windhoek).

1.3.2 Historical trends in rainfall in Namibia

Detecting trends in rainfall is typically more difficult than detecting trends in temperature, especially in highly variable arid climates such as Namibia. This is largely because a single extreme rainfall event can contribute a significant proportion of the annual rainfall in some regions. Figure 1.3 shows how rainfall has varied (as an average over 4 years) between 1901 and 2000 in both southern (figure 1.3a) and northern (figure 1.3b) Namibia. Unlike the temperature record (figure 1.2) there are no obvious trends during the 100-year period, though the variability is similar with high levels of rainfall (low temperatures) during the 1970's changing to low rainfall (high temperatures) during the later period. Figure 1.4 indicates the average monthly rainfall distribution between 1901 and 2000, demonstrating that most of the country is dry (less than 20mm of rainfall) between May and September, with the onset of rainfall in the north typically occurring in November, spreading southward through December and peaking in February. During March and April, average rainfall retreats northward.

Although there are no obvious trends in rainfall on timescales of 4 years this does not mean that there haven't been changes in rainfall on shorter timescales such as during the start/end of the rainfall season or that daily rainfall amounts have not changed. Subjecting the same rainfall stations in table 1 to tests for trends (since 1960) in these attributes indicated that there have been statistically significant (at the 90% level) increases in the length of the dry season (defined as the maximum number of days with < 1 mm of rain) and decreases in the number of consecutive wet days (with >= 1 mm of rain) at Luderitz, Sitrusdal and Hosea Kutako. Additionally there have been statistically significant increases in measures of rainfall intensity (95th and 99th percentile events as well as the average rainfall falling on a rainy day) at Windhoek.

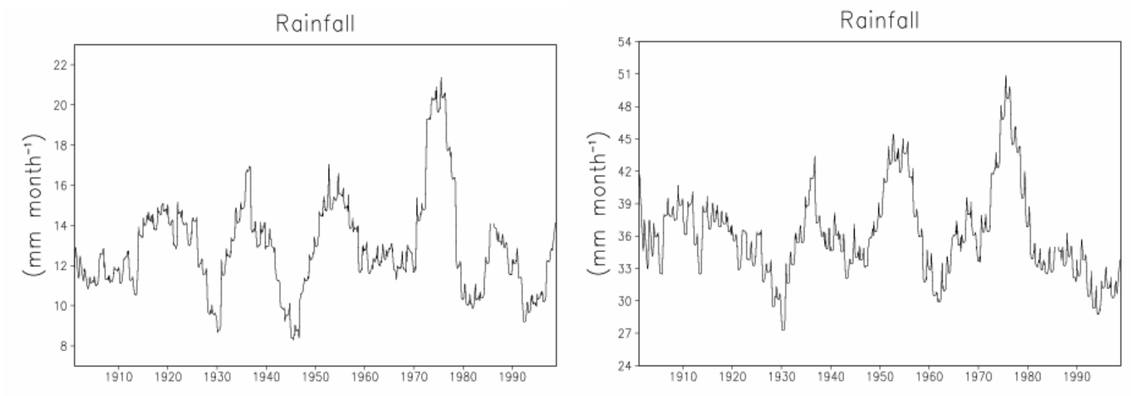
Figure 1.2: **Surface monthly air temperature (°C) measurements 1901-2000: a) southern Namibia (16-20°E, 28-24°S); b) northern Namibia (16-20°E, 22-18°S).**



(a) (b)

Source: Climate Research Unit (Mitchell et al. 2004).

Figure 1.3: **Monthly mean rainfall (mm month^{-1}) measurements 1901-2000: a) southern Namibia (16-20°E, 28-24°S); b) northern Namibia (16-20°E, 22-18°S).**

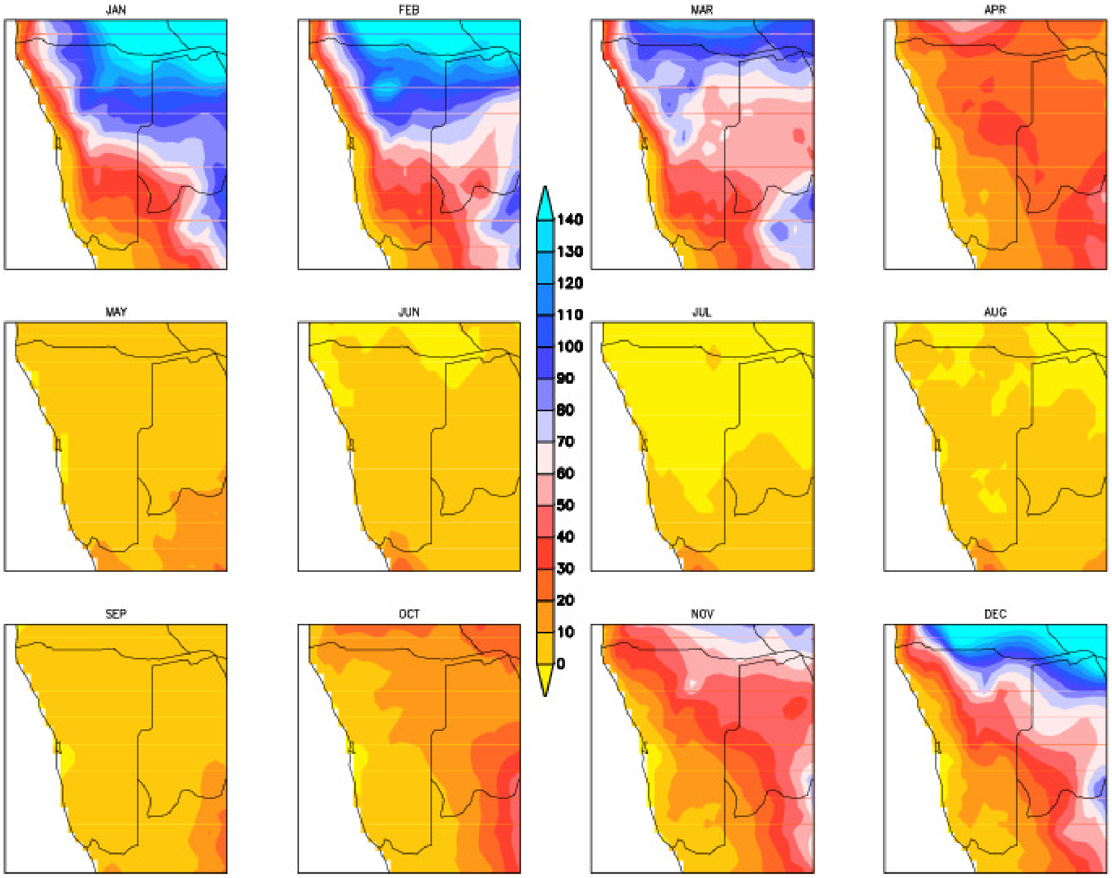


(a) (b)

Source Climate Research Unit (Mitchell et al. 2004).

Using a larger database of 143 rainfall stations trends were calculated on the start, end (days since 1st August) and duration (days) of the rainfall season since 1960 (Figure 1.5). Definitions used for the start (25mm in 10 days not followed by a dry spell of 10 days or longer) and end of the season (3 consecutive 10 day periods of less than 20mm of rainfall) are based on approximate criteria that often define the period during which maize can successfully grow. The criteria for the start is sensitive to dry spells at the beginning of the season, though other criteria related to a more intense start to the season (45mm in 4 days) indicate similar patterns. Whilst there is considerable spatial heterogeneity in the trends, the far northern and central regions of Namibia can be seen to have had a tendency for mostly positive trends in the start of the rainfall season (implying a later onset of rainfall in later years, figure 1.5a) and negative trends in the end of the season (implying an earlier cessation of rains in later years, figure 1.5b). Together these trends result in negative trends in the duration of the rainy season (tendency for shorter rainfall seasons in later years) in the north, most significantly in the westernmost stations. This tendency for a shorter rainfall season is consistent with the trends for a longer dry season noted above.

Figure 1.4: **Monthly mean rainfall distribution (mm month^{-1}) 1901-2000.**



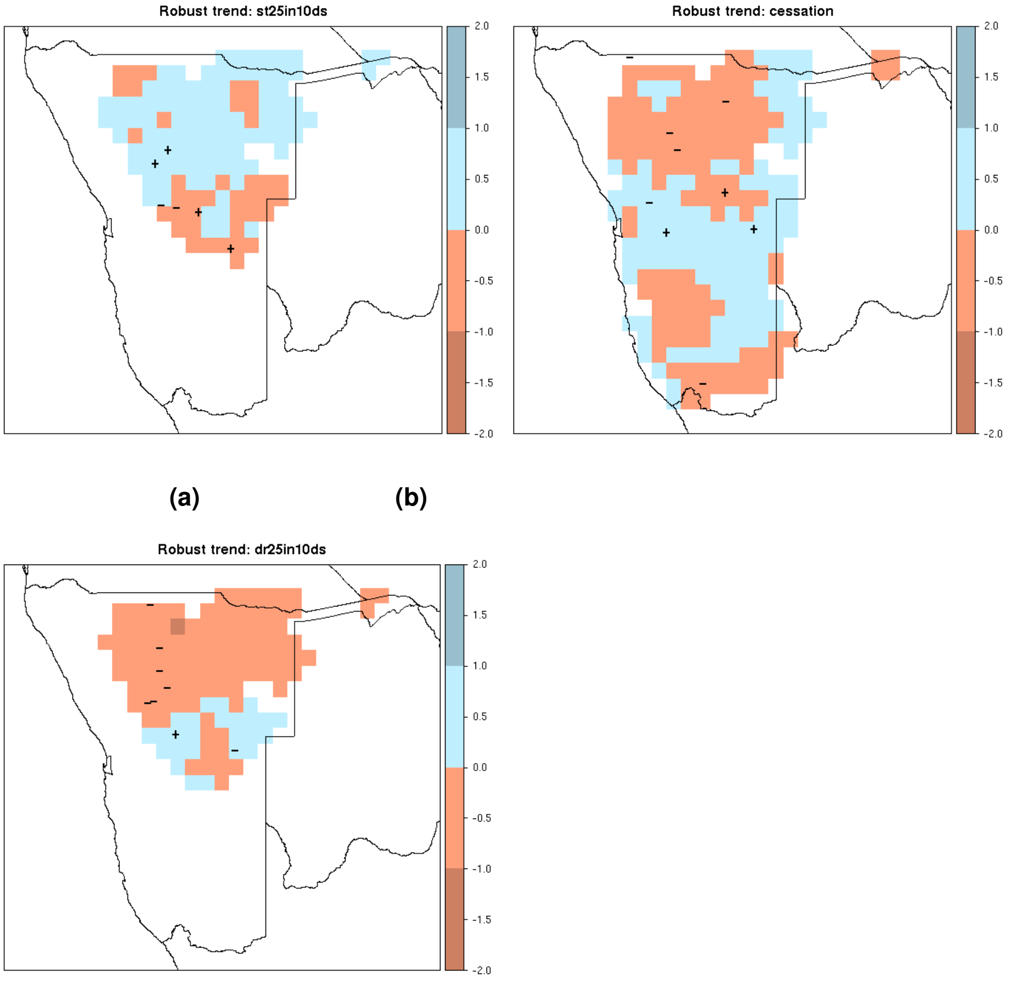
Source: Climate Research Unit (Mitchell et al. 2004)

1.3.3 Historical trends in atmospheric circulation around Namibia

Whilst there have been few studies of trends in the atmospheric circulation over Namibia, (Hewitson et al. 2006) note a trend for a increase in the daily frequency of higher pressures over the continent during the December – February period between 1979 and 2001. Such changes in atmospheric circulation would suggest a lower frequency of rainy days in the latter period during this time of year and this is confirmed over Zambia, Zimbabwe and Malawi (Tadross et al. 2007). Whilst there was an indication of similar changes in the Namibian stations, these were not consistent across large spatial regions.

The changes in atmospheric circulation are however consistent with changes noted in the Southern Annular Mode (SAM), which is the dominant mode of circulation variability in the southern hemisphere (Marshall et al. 2004); (Solomon et al. 2007). Since 1979 the SAM has tended towards a positive polarity, a consequence of lower pressures over the Antarctic and higher pressures further north between 40 and 50°S. This change is consistent with those expected due to increases in greenhouse gases (Arblaster and Meehl 2006) and is therefore likely to continue in the future. A local manifestation of this change may be the long-term increase (modulated by decadal variability) noted in southerly winds, which induce upwelling (cold surface water) off the Namibian coast.

Figure 1.5: **Trends in a) start (25 mm in 10 days not followed by a dry spell of 10 days or longer), b) end (3 consecutive 10 day periods of less than 20mm) and c) duration (end – start) of the rainfall season since 1960 (days year^{-1}). Station trends are kriged (143 stations) and statistically significant positive/negative trends are indicated by "+"/"-".**



(a) **(b)**

(c)

1.4 *Climate projections*

1.4.1 Data and methods applied in climate projections

General Circulation models are the fundamental tool used for assessing the causes of past change and projecting change in the future. They are complex computer models, which represent interactions between the different components of the climate system such as the land surface, the atmosphere and the oceans. In making projections of climate change, several GCMs are used to predict the future. This leads to a suite of possible futures, each of which is a valid representation of what the future climate may be. The scenarios in the following sections are therefore shown as a range of future possibilities.

GCMs typically work at a spatial scale of 200-300km, with the scales at which they have skill, i.e. at which they can usefully project the future, typically greater. Whilst this problem is greatest for projections of rainfall, it limits the application of GCM projections for assessments of change at the local scale. Therefore, the technique of 'downscaling' is typically used to produce projections at a finer spatial scale. Downscaling works because the GCMs are generally good at projecting changes in atmospheric circulation (high and low pressure) but poorly translate that information into changes in rainfall.

The downscaled climate change projections presented in the next sections were developed at CSAG and are the outputs from two broadly different downscaling techniques: empirical downscaling of multiple (6) General Circulation Models (GCMs) (Hewitson and Crane 2006) and RCM downscalings using 2 RCMs nested within a single GCM (HadAM3P) (Mitchell et al. 2004; Tadross et al. 2005). The empirical downscaling uses statistical relationships between the GCM large-scale circulation and rainfall to project future changes from multiple GCMs, and as such is a source of information that covers a wide range of uncertainty in the GCM projections.

The empirical downscaling was originally trained on observed daily rainfall records from the stations used in this analysis (taken for the 1979-2001 period from the General Telecommunications System, GTS), with the National Centres for Environmental Prediction (NCEP) reanalysis ((Kalnay and coauthors 1996) used to provide the atmospheric fields. The GTS station data was not available for the same stations as those used in the historic trend analysis and so the nearest available stations were used. The downscaling seeks to represent the spread of rainfall events associated with particular large-scale atmospheric circulations and use the GCM projected changes in atmospheric circulation (under an A2 emissions scenario) to project changes in rainfall (section 1.4.2).

The RCM on the other hand is a physical model of the earth system that includes potential physical interactions between the land and atmosphere that empirical downscaling does not account for and it is applied to simulate changes over a more limited area of the globe at a higher spatial resolution. In this report. two RCMs have been used for analysis of future rainfall trends; the Mesoscale Model 5 (MM5, (Grell et al. 1994) and PRECIS ((Mitchell et al. 2004), both forced with a single GCM (HadAM3P, A2 emissions scenario). The characteristics of each RCM and climate scenario are given in (Tadross et al. 2005)

RCMs however have similar limitation as GCMs regarding rainfall parameterisations ((Tadross et al. 2005), whilst over southern Africa such differences can lead to different projections of change ((Hewitson et al. 2006). Moreover each RCM simulates a hydrological cycle of different intensity; PRECIS rains more often and with a lower than observed intensity, whereas MM5 rains less often and with a higher than observed intensity

Because of these problems with RCM rainfall (and because the RCM downscalings of 1 GCM are only available), the projected changes in rainfall presented in section 1.4.2 are taken from the statistical downscaling of 6 GCMs, three of which were used in the IPCC 3rd assessment report (HadCM3, CSIRO MK II, ECHAM 4.5) and three used in the AR4 (GFDL, MIROC, MRI CGCM). These characteristics of these downscaled projections are presented in (Hewitson and Crane 2006) and (Christensen et al. 2007). Recognising that there may be processes which the empirical downscaling fails to capture, in section 1.4.5 the RCM is used (in comparison with the GCMs) to simulate rainfall as a check to see if this technique would likely produce different results, i.e. as a cautionary note against placing too much emphasis on the empirical projections.

Given the greater spatial homogeneity and therefore reduced need to downscale, projections of changes in temperature and wind are taken from 13 GCMs used in the AR4 and taken from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset[1]. These models are summarised by presenting the minimum, mean and maximum future change from the 13 models.

All future scenarios are for the period 2046-2065 and are taken from the IPCC A2 SRES scenario, which assumes (conservatively) that society will continue to use fossil fuels at a moderate growth rate. The precipitation data was linearly scaled to this period from downscaled projections for the 2081-2100 period. The choice for the period 2046-2065 (rather than 2081-2100) is based on the need to combine good practice in climate research with the need to take a time horizon that is not too far beyond Vision 2030. That the report does not present information for a time horizon in the near future (i.e. 2021 – 2040) is further informed by the unavailability of archived downscaled IPCC data for such a period.

1.4.2 Future regional climate scenarios: Rainfall

Figure 1.6 indicates the median of projected changes in total monthly rainfall change from the 6 statistically downscaled GCM rainfall estimates. Regions where 3 models (50%) indicate wetting and 3 models drying are left blank, as are regions which increase less than 10mm month^{-1} (the increase in potential evapotranspiration). To evaluate these projected changes the following discussion concentrates on the sign of the change (positive or negative), recognising that there is likely more consistency between models and that estimating the magnitude of change is more problematic.

The most consistent changes are for an increase in late summer rainfall over major parts of the country, and a decrease in winter rainfall in the south and west of the country. Increases in rainfall are most obvious during the January to April period, especially in the central and north-eastern regions. The signals for the Cuvelai area are however not conclusive. Decreases in the southwest are suggested for most months, except February and March but they are particularly widespread during the core winter months.

These projected changes are consistent with the process-based understanding of how climate change will manifest itself over southern Africa i.e.

- That winter storms will retreat southward, reducing winter rainfall to the southern and especially the southwestern parts of the country;
- Increases in thermal heating, coupled with increases in atmospheric moisture, especially during mid to late summer, will increase convective rainfall over much of the country.

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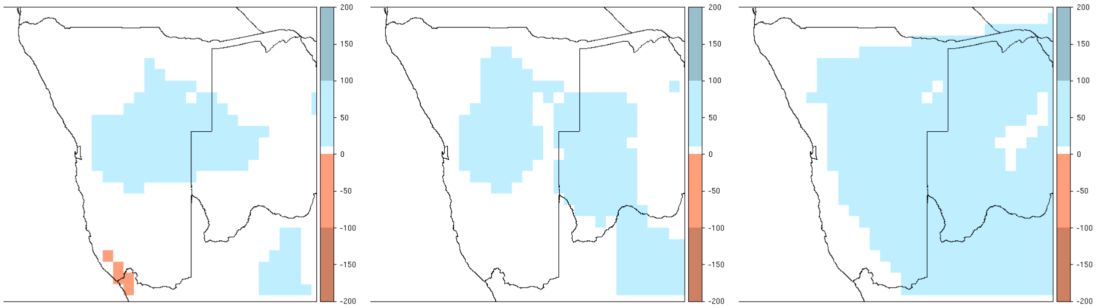
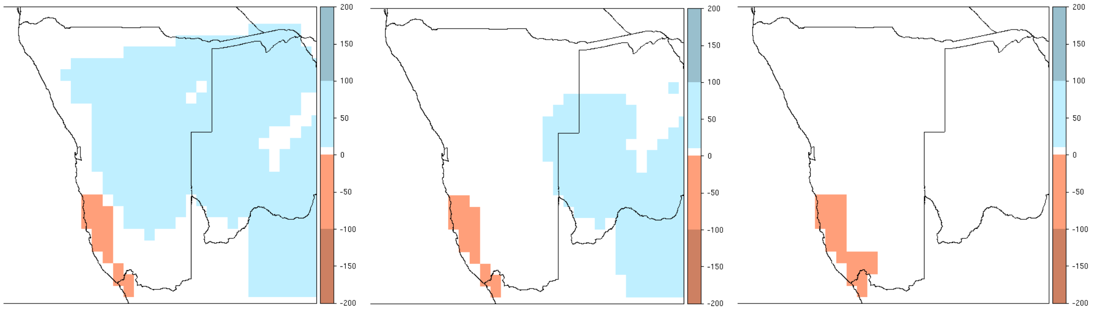
[1] http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php

Figure 1.6: Median change in total monthly rainfall (mm month^{-1}) from the 6 statistically downscaled GCM rainfall projections. Regions where 3 models indicate drying/wetting, as well as experiencing increases of less than 10mm month^{-1} (less than increases in potential evapotranspiration) are left blank.

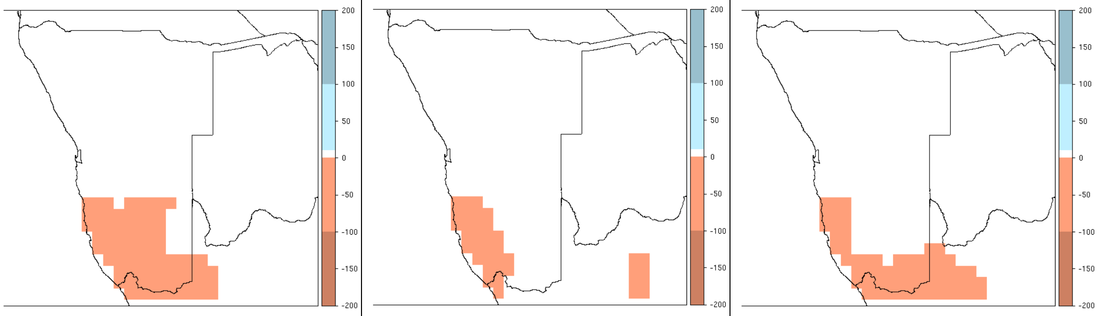
JANUARY **FEBRUARY** **MARCH**

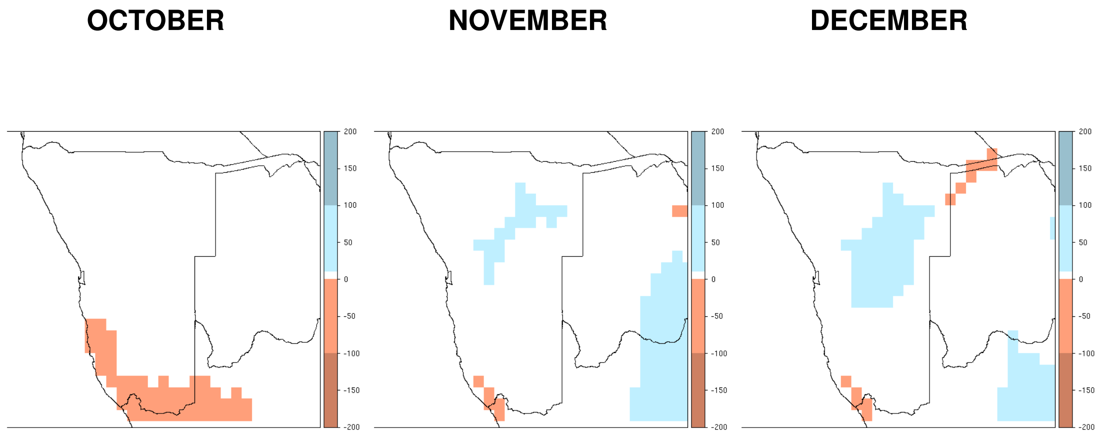


APRIL **MAY** **JUNE**



JULY **AUGUST** **SEPTEMBER**





1.4.3 Future regional climate scenarios: Temperature

Figure 1.7 indicates the minimum, mean and maximum expected change in surface temperature for the 2046-2065 period for both the summer (figure 1.7a) and winter (figure 1.7b) periods. Changes are a minimum towards the coast and increase further inland during all seasons, with minimum expected increases during summer of 1°C -2°C and maximum changes of 2°C -3.5°C. Maximum projected increases in temperature are slightly higher during winter (2.5°C -4°C) whereas the minimum projected increases are similar to those during summer.

It should be noted that downscaling using Regional Climate Models (a higher resolution version of a GCM) may reduce these estimates of temperature change by a few 10ths of a degree (Tadross et al. 2005) partly because they better resolve complex topography.

1.4.4 Future regional climate scenarios: Wind

Figure 1.8 presents the minimum, mean and maximum expected changes in surface wind for the 2046-2065 period from the 13 AR4 GCMs. During summer (figure 1.8a) minimum changes are mostly around zero whereas maximum changes are for onshore flow from the southwest, which are highest (approximately 0.8 ms^{-1}) towards the south. The mean changes are of a similar pattern (though lower magnitude) to the maximum changes and are consistent with increased convective activity and an associated low-pressure trough over the continent during summer.

Both mean and maximum wind changes during winter indicate a similar (though stronger – approximately 1 ms^{-1}) pattern of change to that during summer. However, the minimum projected change also indicates increases in winds from the southeast over the ocean towards the south. Indeed both the maximum and mean projected changes also indicate increases in the southerly component of wind over the ocean. These projected changes are consistent with a retreat of mid latitude storms (which normally bring northwesterly winds) towards the south and an increase in the south Atlantic high-pressure system which drives winds from the south.

Figure 1.7: **Minimum (left), mean (middle) and maximum (right) projected change in a) January-March and b) July-September mean surface air temperature (°C) from 13 GCMs**

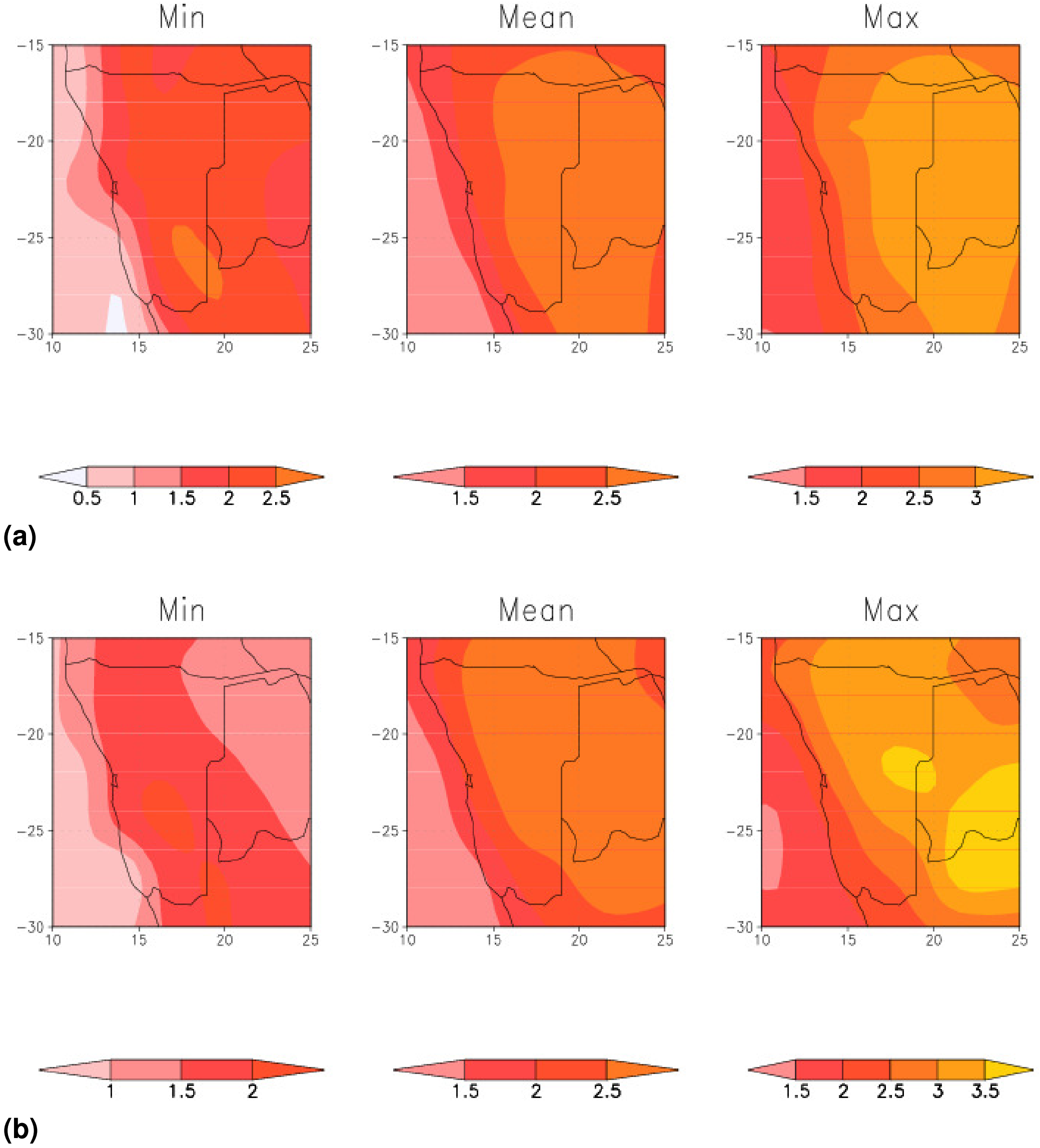
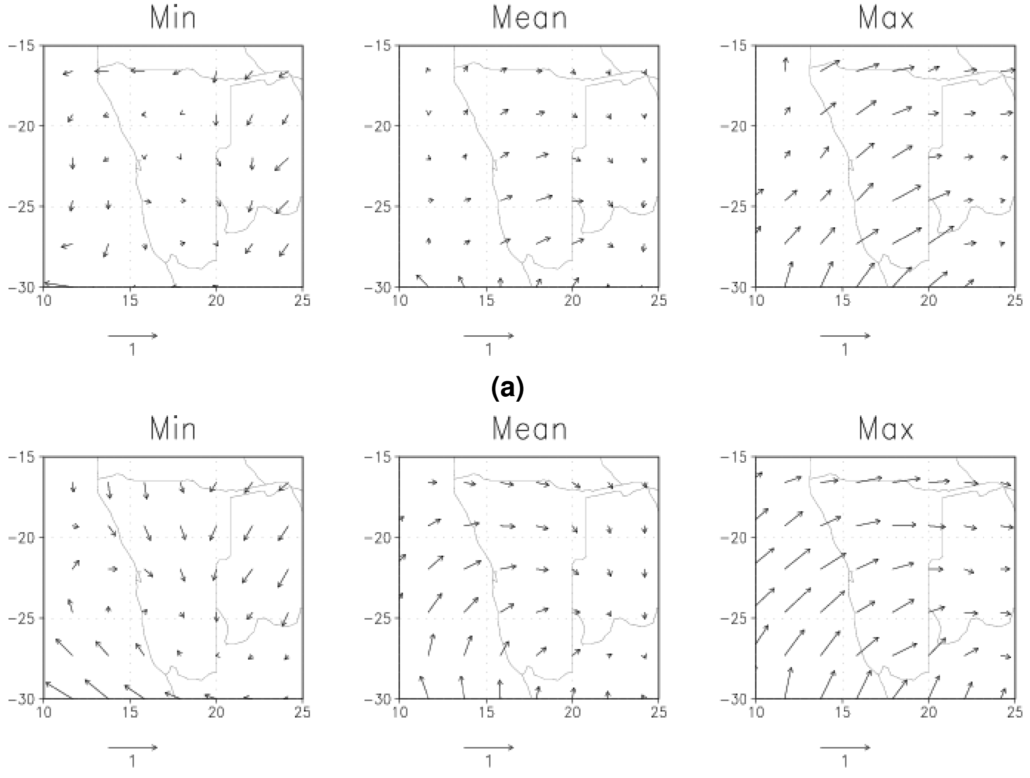


Figure 1.8: **Minimum (left), mean (middle) and maximum (right) projected change in a) January-March and b) July-September mean surface wind from 13 GCMs**



(a)

(b)

1.4.5 Future change at selected stations

To better illustrate the future projected changes in rainfall and temperature we have selected 3 stations (00068029 to represent Caprvi; 00068014 to represent the Otjozondjupa region; 00068312 to represent the Karas region) at which there are available a range of projected future data (for the 2046-2065 period), namely: empirical downscaling of rainfall from 6 GCMs; dynamical downscaling of 1 GCM using 2 RCMs; and the original GCM data itself. We have selected these sites as the present study is concerned with the Caprivi and Karas regions. The Otjozondjupa region lies between the two and is also a region of agricultural productivity. That these stations do not exactly coincide with regions that are undergoing further impact analyses, i.e. crop modelling at Rundu and flood risk for the Zambezi catchment, does not invalidate their representation of climate changes expected at these other nearby sites. As will be demonstrated below there are coherent and similar changes expected across all three stations, e.g. increased temperatures and rainfall during late summer, and the uncertainty of predictions from multiple models is often greater than the uncertainty due to location. This is not to say that different changes might not be expected in different climatic zones, e.g. the coastal regions where winter rainfall is a significant factor. The following discussion concentrates on the sign of the change (+ve/-ve), recognising that the greatest uncertainties lie in projecting the magnitude of change (IPCC 2001).

Figure 1.9: **Station 68029 (Kazungula). Empirically downscaled mean change (for the 2070-2090 period) for 6 GCMs (boxplots) and 2 RCMs (Blue/Red dots); a) total monthly rainfall (mm), c) monthly number of rain days >2mm. RCM-scaled temperature change (K) (for 5 GCMs); b) maximum temperature, d) minimum temperature.**

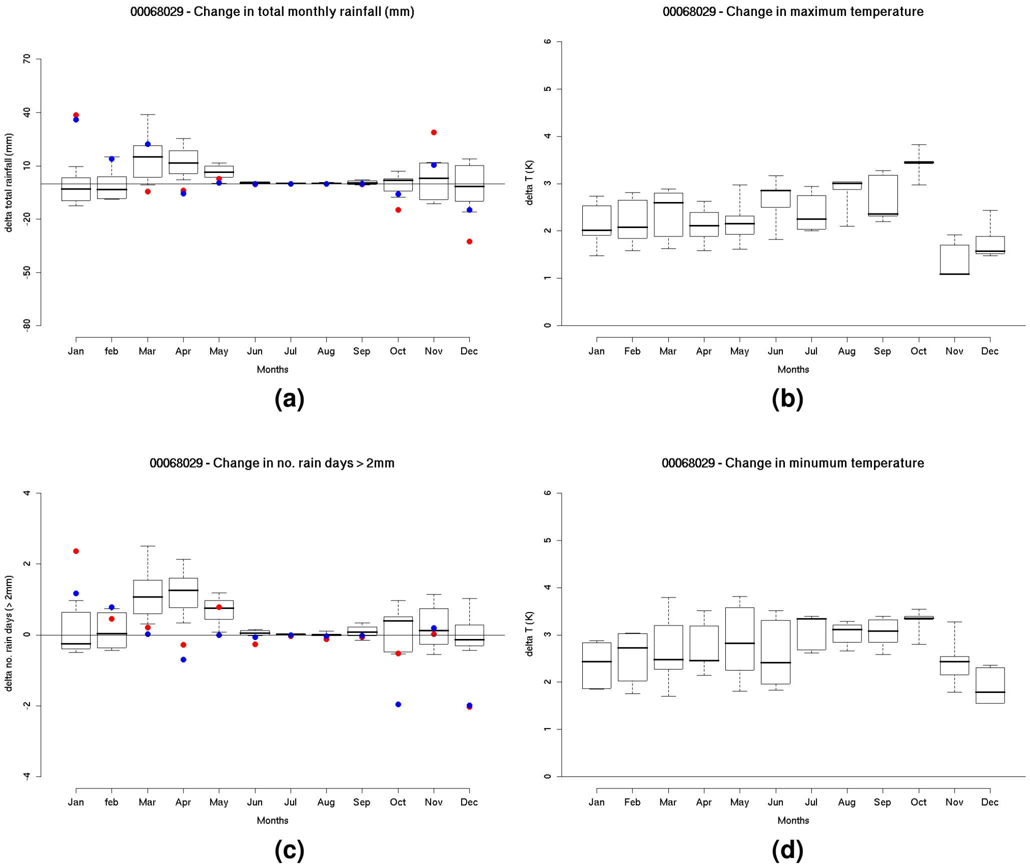


Figure 1.9 presents the monthly changes expected (by approximately 2055) for total monthly rainfall (a), maximum monthly temperatures (b), monthly number of raindays (c) and minimum monthly temperatures (d) at station 00068029 (Kazungula). Boxplots represent the range of projections from the downscalings of multiple GCMs; rainfall from the empirical downscaling and temperature from the RCM-scaled GCM temperature. The blue/red dots in the rainfall figures indicate the rainfall changes from the RCMs. Total monthly rainfall changes from the empirical downscaling suggest a late summer wetting during March-May but at other times of the year are suggesting a range of both positive and negative (undetermined) changes. The RCMs suggest a very weak drying during March-May. Similar results are seen for monthly raindays (figure 1.9c) with the consistent message of late summer wetting at this station. Both maximum and minimum temperatures are projected to rise in all months, with minimum temperatures on average rising more than maximum temperatures and maximum increases of 3-4 °C in October. The sharp drop in temperature increases between October and November are likely in part due to the increase in rainfall in the RCM during this transition, highlighting that these temperature projections are at least partly dependent on the RCMs hydrological cycle and ability to simulate rainfall changes; they should therefore only be taken as an approximate guide to future change.

Figure 1.10: **Station 68014 (Grootfontein). Empirically downscaled mean change (for the 2070-2090 period) for 6 GCMs (boxplots) and 2 RCMs (Blue/Red dots); a) total monthly rainfall (mm), c) monthly number of rain days >2mm. RCM-scaled temperature change (K) (for 5 GCMs); b) maximum temperature, d) minimum temperature.**

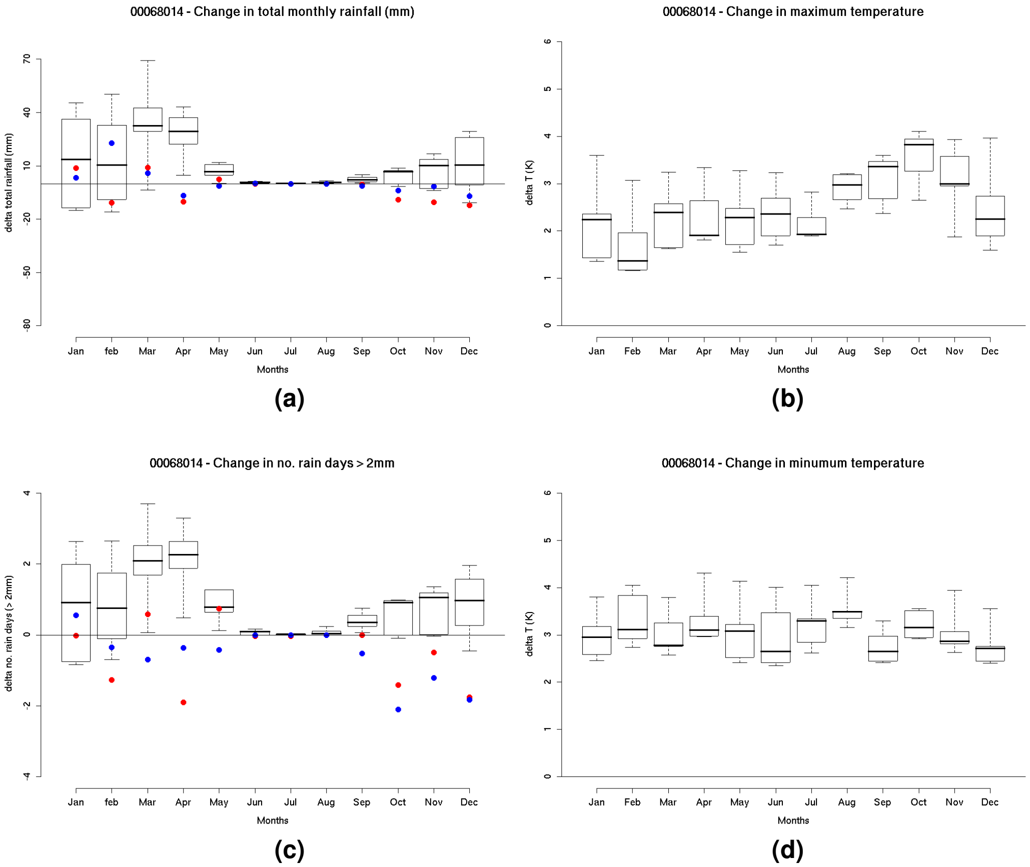


Figure 1.10 presents similar data to figure 1.9 except for station 00068014 (Grootfontein). Increases in total monthly rainfall are seen in the empirical downscaling projections in both the early and late summer months (higher increases than those projected for Kazungula), though again the RCMs would seem to disagree on the sign of the change during the early summer period. Changes in the number of raindays again reflect those for total monthly rainfall, and similar ranges of temperature change are suggested as for Kazungula. It is noticeable that the high increases in maximum temperature during early summer coincide with a reduction in the number of raindays in the RCMs, suggesting that these may be tied to both reduced latent cooling and increased incident shortwave radiation in the RCM. Again we are cautious about over-interpreting these high temperature changes as they are likely influenced by potential biases in the RCM.

Figure 1.11: **Station 68312 (Keetmanshoop). Empirically downscaled mean change (for the 2070-2090 period) for 6 GCMs (boxplots) and 2 RCMs (Blue/Red dots); a) total monthly rainfall (mm), c) monthly number of rain days >2mm. RCM-scaled temperature change (K) (for 5 GCMs); b) maximum temperature, d) minimum temperature.**

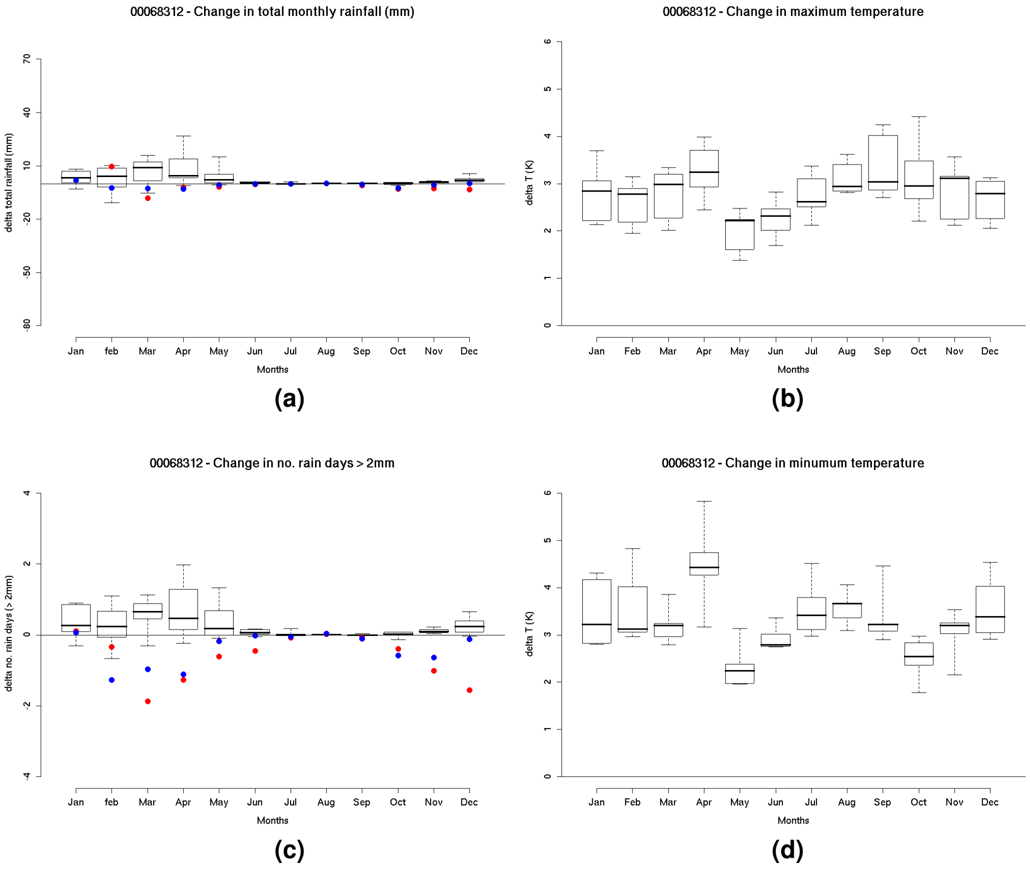


Figure 1.11 indicates changes that are not dissimilar to those noted for the other stations, except that empirically downscaled rainfall changes are smaller in magnitude, especially during early summer (mostly negligible). Temperature changes are similar to the other stations, though maximum temperatures increase less in May – again likely due to changes in the RCM affecting the surface energy balance.

The empirical rainfall downscalings therefore indicate some consistent changes across all three locations (increases in late summer rainfall, of greater magnitude towards the north and east) whilst some changes are more consistent at particular locations (e.g increases during early summer at Grootfontein). However, the RCM rainfall for the same downscaled GCM is sometimes in disagreement; this mostly occurs during early summer, suggesting that there may be some processes not fully represented in either the empirical downscaling or the GCM driving fields at this time of year. These processes may be linked to land surface – atmosphere feedbacks, which are currently topics of active research.

Temperature changes are more consistently predicted and are positive everywhere for both minimum and maximum temperatures. The range of projected changes is wide, though those changes presented here are dependent on the PRECIS RCM from which they are all derived. In the future empirically downscaled temperature projections will become available though it is important to understand that the sign of the change (i.e. positive) will not be different, only perhaps the magnitude; the changes shown here are consistent with those seen in the latest report of the IPCC (Christensen et al. 2007).

1.4.6 Comparison of the observed trends with the projected changes

It has been demonstrated that there have been noticeable changes in climate extremes and rainfall seasonality in the observed historic climate trends in Namibia since 1960. These changes are mostly seen in increases in the hot extremes of temperature and decreases in the cold extremes of daily temperatures, as well as in the frequency of days with temperatures above 25°C and 35°C and days with minimum temperatures below 5°C. Rainfall changes are seen in increased length of the dry season and decreases in the number of consecutive wet days, with a concomitant later start and earlier cessation of the rainy season in the north. In this context it should further be noted that the tendency towards a drier climate may be partly offset by increases in rainfall intensity at some locations e.g. Windhoek, though there has been an overall tendency towards smaller rainfall totals in the north. The observed changes in temperature extremes, the length of the dry season and rainfall intensity not only underscore that the climate in Namibia tends to become drier, but also that climate variability is as significant a phenomenon as the long-term climate trends.

Climate projections for the winter period in the mid century based on six statistically downscaled GCMs suggest a drying in the southwest for most months, except February and March but they are particularly widespread during the core winter months. During summer the consistently projected change is for an increase in rainfall over much of the country. Increases in rainfall are most obvious during the January to April period, especially in the central and northern regions. In terms of temperature minimum projected temperature changes for the summer and winter periods range from 1°C to 2°C across the country. Maximum projected changes range from 2°C to 3.5°C in summer and from 2.5°C to 4°C in winter.

Empirically downscaled climate change scenarios, for three representative stations, support such temperature changes and further suggest that increases in late summer rainfall (total and number of rain days) can be expected over Caprivi, Karas and the area around Grootfontein. Rainfall downscalings for early summer are relatively uncertain, depending on location; the RCM projections (and those in (Christensen et al. 2007) at this time of year are mostly negative, even when empirical downscalings are positive, suggesting increased uncertainty in projections at this time of year.

The projected changes for the middle of the 21st century that have been demonstrated here are linked to physical changes in the regional climate system, which offers a way to reconcile observed trends and future projected change where they disagree. Consistently projected future change is a consequence of the following physical changes:

- Increases in temperature which promote convective activity associated with a predominance of low pressure systems and related wind patterns, especially during mid-late summer
- Increases in humidity, which increase the amount of moisture available for rainfall once it is triggered.
- Retreat of the mid-latitude storm systems and increases in the continental high pressure system during winter (and potentially autumn and spring)

However, these changes in the physical system will interact and couple in a non-linear manner and individually manifest themselves at different periods in the future. The regional expression of change is therefore dependent on which mechanisms, which may compete with each other (e.g. increases in rainfall may offset decreases in rain days), are dominant at any particular time. So, notwithstanding the average trends reflected in the projections discussed in this chapter, referring to the observed historic climate trends that substantiate the natural climate variability in Namibia, the latter serves to underscore that variability is likely to remain a key aspect of the Namibia's climate in the future. More information may however need to be collected about extreme weather events and more modelling is required to determine and understand the inter-annual variability of the climate in Namibia in the future.

It should also be remembered that unlike the temperature signal due to climate change, which is expected to be currently observable, the rainfall signal (as estimated from low variability GCM data – hence likely a conservative estimate) is not expected to be strongly observable for several decades (70-90 years) (Christensen et al. 2007). As such, allowing for uncertainty in the changes simulated with CO_2 forced climate change, the projected changes are not at odds with changes noted in the observational record, though statements of attribution are not easily made.

In particular the projections of increased late summer rainfall, whilst currently inconsistent with the observed trend for an earlier end to the season, are more consistent across models, which suggests that this aspect will contribute to future change. Furthermore, there are suggestions of increases in rainfall intensity in the observed record, which is consistent with increases in humidity and convection and can be expected to become more apparent in the future.

2 Vulnerability to climate change in Namibia: the socio-economic context

2.1 Introduction

Climate change literature is beleaguered by uncertainties. An issue which is without contention however is that Africa will be negatively affected by climate change, partially as socio-economic conditions exacerbate the vulnerability of the population on the continent. As such (Galvin et al. 2004) expect that climate change will affect the attainment of most of the Millennium Development Goals, most importantly the goals to eradicate extreme poverty and hunger, reduce child mortality, combat disease and ensure environmental sustainability. In this chapter an attempt is therefore made to draw attention to the most important socio-economic factors contributing to vulnerability in Namibia.

Vulnerability to environmental change not only depends on change in frequency or duration of climatic conditions, but also on the capacity to respond adequately to those changes. As such this chapter follows the approach of (Galvin et al. 2004) who distinguish two aspects of vulnerability. The first aspect concerns the likelihood that an individual or group will be exposed to and will be adversely affected by new climatic circumstances. The second aspect of vulnerability relates to the characteristics of individuals or groups in terms of their capacity to anticipate, cope with, resist and recover from the impacts of environmental change. This capacity to adapt to climate variability and climate change obviously varies among regions and socio-economic groups in the sense that those with the least capacity to adapt are generally the most vulnerable to the impacts of climate variability and change. In turn this depends in great part on which resources are available to a given group, individual or region.

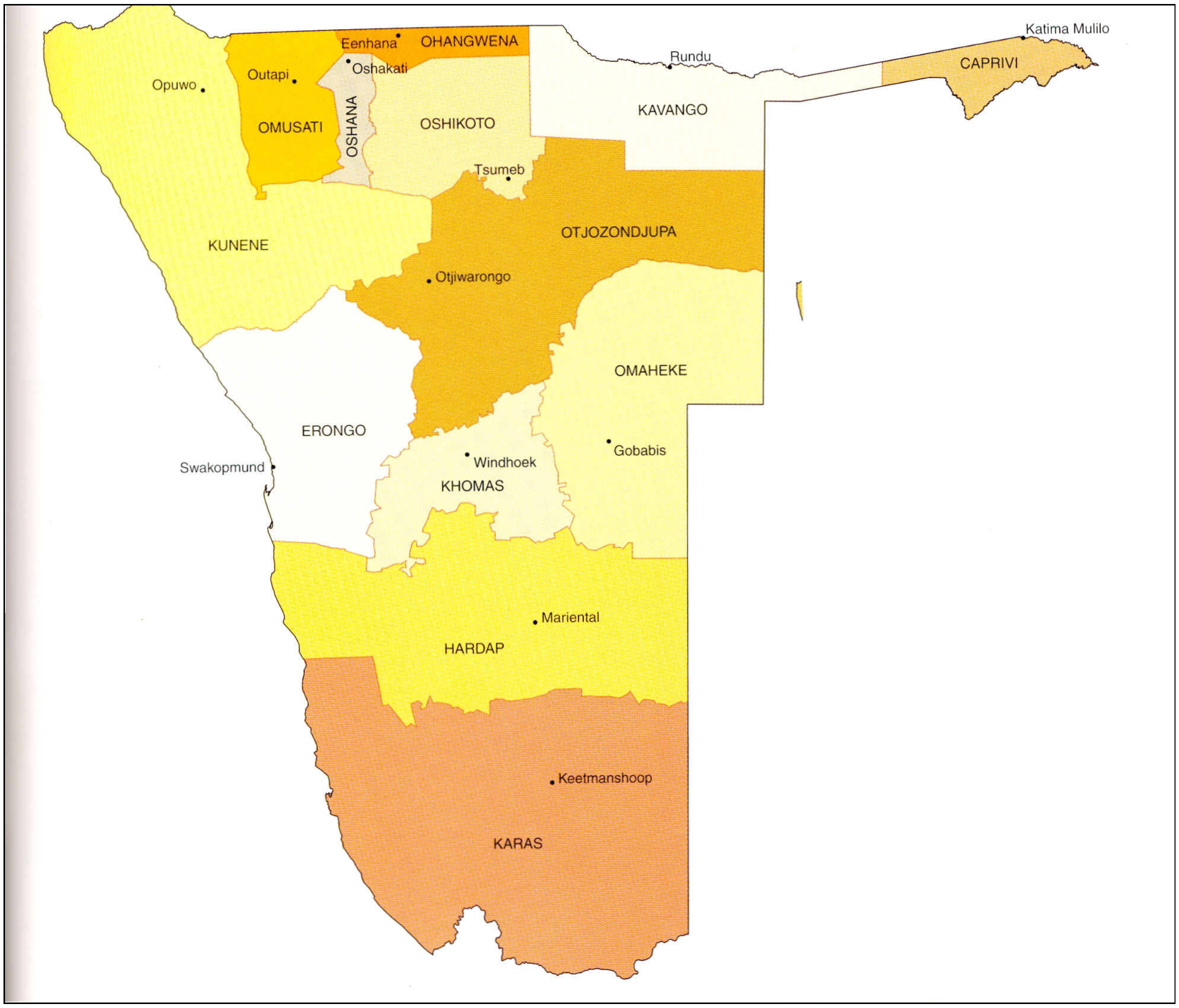
In relation to the adaptive capacity and resource endowment (Leary et al. 2006) inter alia identify household income, income diversification, availability of labour and the health status of household members as factors that determine vulnerability. External factors such as the existence of formal and informal social networks, the availability and quality of health services, and prices of farm inputs and outputs further influence the capacity to cope with and recover from climate shocks. In addition issues of policy, growing populations and low agricultural production contribute to limited adaptive capacity and ultimately, vulnerability.

In line with these insights the following sections present an overview of various aspects of human development, including income and poverty, education, health and access to resources and services in the Caprivi, Hardap and Karas regions. Reference is made to statistics as far as possible, qualitative information has been added where it provides relevant insights. Emphasis is placed on the Caprivi and Karas region as per the Terms of Reference for this assessment; information on Hardap has been added, as a major part of the Fish River Basin – studied in-depth in the chapter on the water sector - lies in this region.

2.2 Geographical characteristics and livelihood systems

The Caprivi region in North-eastern Namibia and the Karas and Hardap regions in the South-west embody the environmental and economic contrasts Namibia’s rural areas offer. The natural environment of the Caprivi region is characterized by relatively fertile soils and savannah vegetation. Wetlands are an important feature in the landscape of Caprivi, as the region is bordered and dissected by the Zambezi and Kwando-Linyanti rivers which run throughout the year. Every so many years the confluence of waters from the respective rivers results in flooding of low-lying plains in the eastern part of the region. The region is further characterized by productive aquifers across the region and receives in excess of 550 mm precipitation annually, with rather low variability and relatively low evaporation levels.

Figure 2.1 The regions of Namibia



Source: (Mendelsohn et al. 2002)

These natural conditions imply that the regional livelihood system is based on subsistence-oriented maize cultivation, which is combined with a small number of goats and cattle for domestic purposes, supporting approximately 12,000 farming households (Mendelsohn 2006). The cereals are usually cultivated in communal land on small plots that surround people's homes, whilst livestock is largely grazed on open access common pastures and woodlands. In fact the region has an excess carrying capacity for livestock, although the population density is a multiple of that in the vast Karas region (5.5 versus 0.4 persons/km² respectively; (Republic of Namibia 2003a). Thus, cattle densities in the area around the flood plain in the Caprivi are more than 10 head/km², whilst they hardly reach to 1 head/km² in Karas (Mendelsohn 2006).

Livelihoods in the eastern part of the region further depend on the interchange of the seasonal flow of water from the Zambezi, Kwando and Lyanti rivers, which causes flooding of the flood plain. These wetlands have a natural capacity to absorb large amounts of water and allow for 'regression farming' of maize and seasonal fishing. They further provide substantial opportunities for tourism, as it attracts birds and wildlife that migrate between Botswana, Zambia and Namibia. Livelihoods used to be flexibly organized around this seasonal movement of water, as cattle and people used to be moved temporarily to higher elevations when the water levels in the floodplain became high. Nowadays, the region is considered vulnerable to flooding of the wetlands, as high stream flow of the Zambezi puts infrastructure that has been established in the flood plain at risk and makes economic life and access to schools, clinics and government services more difficult in times of 'flooding'.

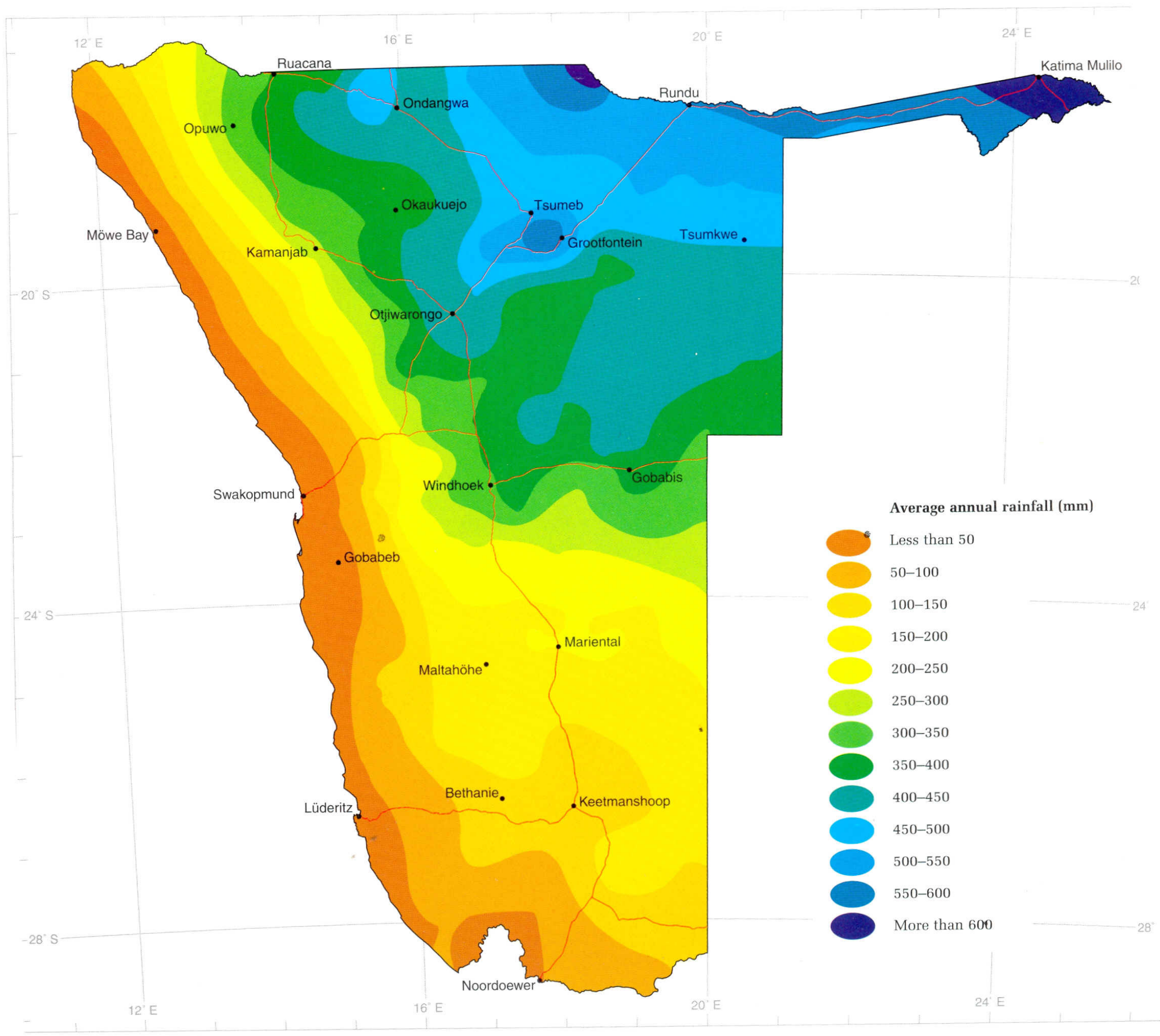
Vulnerability to climate change is likely to be determined by changes in rainfall intensity (later onset, possibly heavier rains) over the Kavango and Zambezi catchments in Angola and Zambia, decrease in total precipitation, run-off and perennial drainage and further informed by the loss of traditional coping mechanisms and other socio-economic trends discussed later in this chapter.

Natural conditions and livelihood systems in the Southern regions of Namibia are very different from the Caprivi. Annual precipitation varies between 0 and 160 mm per annum in Karas and ranges from less than 50 mm in the west to 250 mm in other parts of the Hardap region. Rainfall in both regions is characterized by high seasonal variation, and fog days per annum play an important role in the coastal ecosystem. The west-draining Orange river catchment which forms the southern border of the Karas region carries little water and groundwater is very scarce in both regions. Whilst vegetation is generally dominated by shrubs as in most semi-deserts, there are only very small pockets of medium soil fertility in the southern regions, with the rest of the soils too poor to be suitable for cropping. Rural production is therefore dominated by raising small stock such as goats and sheep (Mendelsohn 2006).

In the Karas and Hardap regions title deed land dominates. More than 214,000 km² or 77 percent of farm land in these regions is being farmed by approximately 2,000 land owners on freehold farms ranging in size from 7,000 to 15,000 hectares. Another 61,000 km² (23 percent of farm land) belongs to open access communal land in the so-called Bondelswarts, Hoachanas and Warmbad reserves and the former Namaland in Hardap and Karas, which is farmed by approximately 6,300 households. The rangelands carrying capacity is, at best, a third of Caprivi's and as livestock production is the major livelihood source for the majority of rural people in the region, rangelands are perpetually overstocked, especially around water points (Mendelsohn 2006). In addition to cattle farming, large scale irrigated farming (grapes, dades etc.) occurs along the Orange river, whilst scenic beauty in catchments of the Fish and Orange rivers has lead to an increase in tourism activity over the past few decades.

Vulnerability to climate change in the Karas and Hardap regions is expected to be determined by the impact of trends in drying on the western side of the sub-continent, which will likely result in more frequent droughts, higher variability of already very limited rainfall, generally longer dry spell duration and an expected decrease in run-off and perennial drainage –also affecting the Orange river. The question is therefore how the population will adapt to the even drier future conditions.

Figure 2.2 Average annual rainfall in Namibia



Source: (Mendelsohn et al. 2002)

2.3 Demography and population growth

In 2001 the Namibian population amounted to 1,830,330 individuals. The population of Caprivi comprised 79,826 persons. Nearly 70,000 persons were living in the Karas (69,329) and Hardap regions (68,249) in 2001. Caprivi is a relatively densely populated region with 5.5 persons per square kilometer. The Hardap and Karas regions comprise vast areas and are thus far less densely populated than the Caprivi; densities amount to 0.6 and 0.4 persons per square kilometer respectively (Republic of Namibia 2003a).

Whilst in the Caprivi and Hardap regions the majority of the population in 2001 was predominantly rural (67% and 72% respectively), only 46% of the population of Karas was classified as rural; more than half of the population of this region lives in medium sized towns such as Keetmanshoop, Aussenkehr, Rosh Pinah and Luderitz (Republic of Namibia 2003a).

In terms of age composition the population of Namibia and its regions is characterized as a relatively young population. In 2001 39% of the Namibian population was younger than 15 years of age. Similarly young population structures are found in the Caprivi, Hardap and Karas regions, where the share of the population below 15 years in 2001 amounted to 38%, 36% and 31% respectively (Republic of Namibia 2003a).

Although the fertility rate in Namibia came down from 6.1 to 4.1 between 1991 and 2001, with 5.1 persons the average size of a household in Namibia is still fairly large. In Caprivi households on average are slightly smaller (4.7 persons) than in Namibia. The same goes for the average household size in Hardap (4.4 persons) and Karas (4.1 persons) (Republic of Namibia 2003a).

Such figures for average household size and age composition of the regional populations imply that dependency ratio's (defined as the ratio of the total population to the employed population) in the three regions are relatively favourable. In Caprivi, Hardap and Karas between 3.5 to 4 persons are supported by a working person, whereas an employed person in rural Namibia on average needs to support close to 6 other persons.

Table 2.1: Fertility rates in Namibia (%), 2001 and 2031

	Fertility rate	
Region	**2001**	**2031**
Caprivi	3.8	2.3
Hardap	3.7	2.5
Karas	3.2	2.1
Namibia	*4.1*	*2.4*

Source: (Republic of Namibia 2006d)

When comparing the life expectancy between the Caprivi and Karas region two near-extremes in Namibian demographics are visible, mostly due to the Caprivi region having the highest HIV/AIDS infection rate in the country (Table 2.2). Life expectancy is however expected to improve towards 2031 across the board, although it is likely to remain lower in the Caprivi region than in the other regions. Fertility rates in the three regions are lower than the national average, however more strongly so in the Karas region (Table 2.1). By 2031 fertility rates are expected to have dropped substantially in all three regions, as well as for Namibia in general.

Table 2.2: Life expectancy at birth (in years) , 2001 and 2031

	2001		**2031**	
Region	**Female**	**Male**	**Female**	**Male**
Caprivi	43	41	50	48
Hardap	53	51	58	56
Karas	61	54	68	63
Namibia	***50***	***48***	***65***	***63***

Source: (Republic of Namibia 2006d)

2.3.1 Population Growth 2001 - 2031

Age composition, mortality and fertility rates are factors that determine the growth rate of a population. Although the fertility rate in Namibia has been reduced substantially over the past few decades and will still diminish according to the population projections of CBS, the population of Namibia is expected to grow substantially until 2031[2]. The tables below demonstrate that a combination of reduced, but still relatively high fertility rates and increased life expectancy would culminate, in part, in significant growth of the Namibian population over the next decades. In fact, by 2031 the population of Namibia is expected to have grown by 66 % to a total of 3,031,463 persons, representing an average annual growth rate of approximately 1.7 percent over the period of 30 years. This projected population figure is based on the medium scenario of the population projections by CBS. Although this is not a very high annual growth rate, the overall increase in population may exacerbate the vulnerability of livelihoods and ecosystems. The pressure on land and water resources is likely to increase in the more densely populated communal areas in the north-central regions and the Kavango and Caprivi regions, if one assumes that land management practices will not change significantly without specific interventions. In 2001 the four north-central regions comprised approximately 43% of the total Namibian population, whilst the six northern regions (including Kavango and Caprivi) altogether accounted for 58% of the population. Expected growth rates towards 2031 range from 21% to 58% for the north-central regions and Caprivi, whilst the population of Kavango will more than double. This implies increased pressure on ecosystems in regions where there is already evidence of land degradation, related to a combination of relatively high population and stock densities and limited implementation of sustainable land management practices. This is underscored e.g. by conflicts around access to grazing areas and the disappearance of perennial grass and tree species around water points.

Table 2.3 Population growth projections by region

Region	Population 2001	Population 2031	Growth over 30 year period
Caprivi	79,826	105,344	32%
Erongo	107,563	122,290	14%
Hardap	68,246	77,521	14%
Karas	69,321	78,748	14%
Kavango	202,690	472,994	133%
Khomas	250,260	638,993	155%
Kunene	68,735	93,552	36%
Ohangwena	228,383	360,382	58%
Omaheke	68,041	110,771	63%
Omusati	228,841	276,005	21%
Oshana	161,917	213,676	32%
Oshikoto	161,006	239,567	49%
Otjozondjupa	135,385	241,170	78%
Namibia	**1,830,330**	**3,031,463**	**66%**

Source: adapted from (Republic of Namibia 2006d)

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[2] No population projection for any later period have been carried out to date.

Figure 2.3: Population projections for the period 2001 to 2031 (persons)

	2001	2011	2021	2031
Caprivi	79826	89125	99179	105344
Karas	69321	73630	77940	78748
Hardap	68246	72483	76726	77521
Namibia	1830304	2184082	2621389	3031463

Source: adapted from (Republic of Namibia 2006d)

Trends in population growth for the Caprivi, Hardap and Karas region and the nation as a whole are presented in Figure 2.3. The trend lines indicate moderate increases in population size in the regions. By 2031 the population in the Caprivi is expected to have grown considerably more (32%) than the populations in Hardap and Karas, which will only increase with 13,5% between 2001 to 2031; the former represents and annual growth rate of approximately 1%, whilst the latter represent annual growth rates of less than 0.5 percent. This implies a substantial reduction of current growth rates. Although little information is available about internal migration, the explanation for such low growth rates in the Caprivi and the South can only be found in relatively high out-migration rates. As far as the Caprivi region is concerned, the growth projections imply that the population density will increase from 5.5 to 6.1 persons/km² by 2031. Such projections may imply that pressure on resources may become a major issue in the near future, all the more if one considers that the population in Caprivi has already increased from around 15,000 individuals around 1950 to nearly 80,000 in 2001 (Mendelsohn and Roberts 1997; Republic of Namibia 2003a). Firewood, construction wood and land with fertile soils and pastures might be become more scarce in the future. Similarly, with increased population densities it might be more difficult to control veldt fires.

In terms of demographic change the rate of urbanization is expected to increase, reducing the impact of population growth in rural areas but bringing with them immense challenges for the few Namibian urban centers. Demand for serviced land and water supply and sanitation services is likely to increase in urban centres and this has implications for the institutional capacity that is required to provide adequate services. The projections of CBS have however not clearly outlined this aspect of demographic change in Namibia, so it is impossible to make sound projections for urbanisation.

2.4 Poverty and vulnerability

Apart from demographic trends, the prevailing levels of income and poverty influence the resource base of households in the regions across the country and this again determines the resilience of households to deal with the impacts of climate change.

Adjusted per capita income in Namibia averaged N$ 10,358 per year in 2003/04, whereas the annual average per capita income for the Karas (N$12,706) and Hardap (N$ 12,092) regions is about twice as high as in Caprivi (N$ 6,411). With these levels of per capita income Karas and Hardap are –together with Omaheke- amongst the 5 richest regions in the country, immediately after Khomas and Erongo. The Caprivi region on the other hand ranks 5th from the bottom after Ohangwena, Kavango, Omusati and Ohikoto (Republic of Namibia 2006a; UNDP 2007).

The low level of per capita income in Caprivi is reflected in the official poverty statistics of the region. The poverty line in Namibia is defined as the share of the population that spends more than 60% of its income on food, the so-called food consumption rate. In Namibia as a whole it amounted to 28.8 % in 2003/04, which was a reduction of 9 percent compared to 1993/94. The food consumption rate in Caprivi however stood at 43.6 % in 2003/04. As such it is the fourth poorest region in the country in terms of income poverty, after Kavango, Oshikoto and Omusati. Using this indicator, in Karas and Hardap only 18.5 % and 27.8 % of the population are classified as poor in 2003/04 (Republic of Namibia 2006a).

The Human Poverty Index to a certain extent underscores the picture based on income poverty. The HPI is a composite poverty indicator which includes three dimensions: the probability of not surviving up to the age of 40, the adult illiteracy rate and the proportion of the population classified as poor according to the food consumption ratio. In terms of the HPI the Karas region ranks as 2nd best with an HPI of only 21, meaning that 21 % of the population is affected by any one of its dimensions. Hardap takes an intermediate position in 2004 with an HPI of 29 percent, whilst Caprivi ranks 4th from bottom in Namibia with an HPI-score of 43 percent. It is noteworthy that the HPI of all three regions rose between 1994 and 2004, meaning that all regions turned poorer than in 1994. This is in contrast with some of the trends in income poverty per se, which revealed a reduction at national level. UNDP attributes the worsening of the HPI to the impact of HIV/AIDS on the population of the various regions of Namibia, which has severely affected the life expectancy and the chance of turning older than 40 years of age (UNDP 2007).

The nature of poverty according to the PPA

Wealth ranking was also undertaken during the Participatory Poverty Assessments in all regions in Namibia. Across six locations in the Caprivi region PPA participants, using their own criteria, classified 54 percent of households as very poor, whilst another 31 percent were classified as moderately poor. The criteria used are indicative of what PPA participants in the respective regions consider important and they provide qualitative insights pertaining to levels of poverty, access to resources and the vulnerability of certain categories of households, often more so than the food consumption ratio or the composite HPI.

The PPA in Caprivi underlined that (extreme) poverty is characterized by the following factors:

- Not having any employed family/household members
- Limited ownership of and access to productive resources. Extremely poor people may e.g. have access to land, but no equipment and animals, such as oxen for ploughing, to work with. Similarly the extremely poor in Caprivi cannot go fishing because they cannot afford nets and canoes.
- Food insecurity. Extremely poor households often cultivate their fields by hand, and their harvests are very small, lasting about two months only, resulting in shortages of food (e.g. eating mostly one meal per day) (Republic of Namibia 2006b).

As far as the Carpivi region is concerned, when households are less poor they tend to have better access to the productive resources referred to above. Often they are also more food secure and tend to depend less on wealthier families in the community for support or temporary employment. This is sometimes related to the fact that a family member has a low-income job. As such employment provides the means to plough in time and to acquire the resources to go fishing (Republic of Namibia 2006b).

Wealthy or rich people have substantially more productive resources and access to a regular fairly well-paid form of employment or businesses. This provides the means to drive a vehicle, to cultivate larger fields by hiring workers or tractors and to trade in cattle as they like.

In Karas the nature of poverty and vulnerability is quite different, due to the more urbanized character of the region. According to the Karas PPA, extreme poverty is merely found in urban settlements and far less in the rural areas (Republic of Namibia 2007b). Extreme poverty in the region is generally related to not having a regular source of income, or reliance on low-income job, a pension or social grant, especially when the latter has to be shared with many household members. As such extreme poverty in the urban areas in the region is associated with a lack of food security (one meal per day), poor shelter or housing conditions, dirty clothes, indebtedness and poor health. It further implies a heavy reliance on friends and neighbours e.g. to obtain water. The living conditions of the very poor in rural areas in Karas seem to be not that extremely harsh; they are merely characterized by not owning any small stock or small herds of up to twenty goats or sheep, or by working for wages that are below the minimum wage of farm workers.

Being poor (rather than extremely poor) in urban areas in the Karas region have some continuous form of income, often a pension and some allowances in the household, which is supplemented by income from piecework and remittances from family members. The income allows poor households to pay for basic services, have more food security, with meals that are often taken more than once a day. It also provides the opportunity to live in fixed houses, brick or zinc structures, rented or owned. In the rural areas in Karas the poor had op to 50 goats and some form of income, e.g. one or two pensions (Republic of Namibia 2007b).

Vulnerability

Specific factors that were mentioned to make people vulnerable in the Caprivi region are natural shocks such as floods for those living in the low lying wetlands, droughts and climate change, livestock diseases and pests. As such dependency on agricultural activities for a livelihood was singled out as a cause of vulnerability, and this was compounded by shortage of productive resources. Other factors that made a family vulnerable were the loss of employment, prolonged illness and the death of the breadwinner in the family. The latter underlines that the HIV/AIDS pandemic is having a major impact in the region. In connection to this participants also stated that a high dependency burden, e.g. caused by orphans, also made families vulnerable.

In the Karas region vulnerability was related to similar factors as in Caprivi, such as loss of employment, disability and sickness (including HIV/AIDS), having many dependents and orphanhood. As in Caprivi alcohol abuse enhanced people's vulnerability considerably. Specific shocks comprised damage to shacks caused by fires, as well as flash floods in informal settlements along the Orange river. In rural parts of Karas drought and water shortages made people vulnerable (Republic of Namibia 2007b)

2.5 Access to productive resources

This section provides a quantitative background to some of the PPA findings presented above. Table 2.4 depicts access to resources in the respective regions and at the national level. Considering the importance of farming as a main source of income in the livelihoods of rural Namibians in general, which underscored that 48% of rural households depend on farming as the main source of income, it is noteworthy that access to farming resources in rural areas is constrained for major shares of the rural population; half of all rural household do not have access to cattle, nearly half do not have access to goats, whilst a quarter of rural households do not have access to grazing land or crop fields.

The table further underlines that the mix of agricultural resources for a Caprivian family mostly consists of cattle, poultry and crop fields. Grazing areas are mostly communal, with a surprisingly large section (close to 33 percent) of the population being excluded from the grazing land, and nearly 20 percent from croplands. Access to resources appears even more constrained in the Karas and Hardap regions, with in excess of two-thirds of the regional residents not having access to the predominant resources required to run a farming enterprise; small stock. As noted earlier farming does play a significantly smaller role in the regional economy of Karas compared to the Caprivi region though.

Such figures further substantiate the vulnerability of primary resource users with limited other livelihood means, an issue that was also raised during the PPA in Caprivi and Ohangwena for example. According to participants to the Caprivi PPA, the very poor lacked many assets, but the moderately poor owned some cattle and owned or could access crop fields. "Having nothing" in terms of productive resources was considered as a characteristic of being (very) poor, which had negative implications for food security. Households which did not own oxen or a plough could not cultivate their fields and struggle to produce sufficient food, as they had to rely on borrowing oxen from better off families, whilst tractors could hardly be afforded by the poor. This usually implies that the poorer households cannot plough at optimal times and are late for timely planting. This is often to the detriment of their crop harvests and further implies that the persons involved had to rely on begging, on piece jobs for other families and on collecting veldt products to sustain themselves.

Table 2.4: Households by access to productive resources (%)

		Cattle	**Sheep**	**Goat**	**Poultry**	**Grazing land**	**Crop fields**
Caprivi	Owns	62.8	-	11.9	53.2	1.1	75.5
	Access	11.1	-	2.2	1.2	70.2	4.4
	Neither	26.1	99.0	85.2	45.1	28.0	19.3
Hardap	Owns	13.0	12.6	27.4	24.5	4.7	2.2
	Access	4.7	6.8	6.2	1.0	28.8	10.3
	Neither	81.8	80.3	66.2	74.2	65.4	85.0
Karas	Owns	16.5	11.1	30.4	26.2	8.5	5.1
	Access	3.0	2.4	2.6	2.2	29.0	15.3
	Neither	80.5	86.5	67.0	71.6	62.4	79.3
National	Owns	33.7	6.4	14.3	48.6	4.7	25.1
	Access	7.1	1.3	1.1	2.3	51.7	29.1
	Neither	59.1	92.1	84.4	48.9	43.5	45.5
Rural	Owns	40.4	7.2	49.7	69.2	4.0	34.8
	Access	9.5	1.5	3.7	1.9	69.6	39.9
	Neither	50.0	91.0	46.3	28.7	26.3	25.0

Source: adapted from (Republic of Namibia 2006a)

Poverty and not owning or having access to productive resources further has implications for one's chance to move out of poverty, as well as for long-term investments. PPA participants in Caprivi were of the opinion that there is inter-generational poverty, as children in poor families are more likely to inherit poverty from their parents. As a poor person you would be left with little resources when parents or other relatives pass away and it was further considered more likely that you develop little or no skills that would help you to move out of poverty. The latter was related to the fact that the poorest are often uneducated and did not attach similar value to education for their children, as middle-class or rich people would (Republic of Namibia 2006b).

Land tenure

Long-term investments of any kind require firm property rights; the tenure arrangements in the communal areas of Namibia (mostly common property resources currently left somewhat in a void between traditional law and newly-established judiciaries not yet functional nor necessarily accepted) do not lend themselves to promote the type of infrastructural investments climate change adaptation would warrant. The chapter on adaptation takes this argument forward.

Current tenure arrangements in Namibia are presented in Figure 2.4 below.

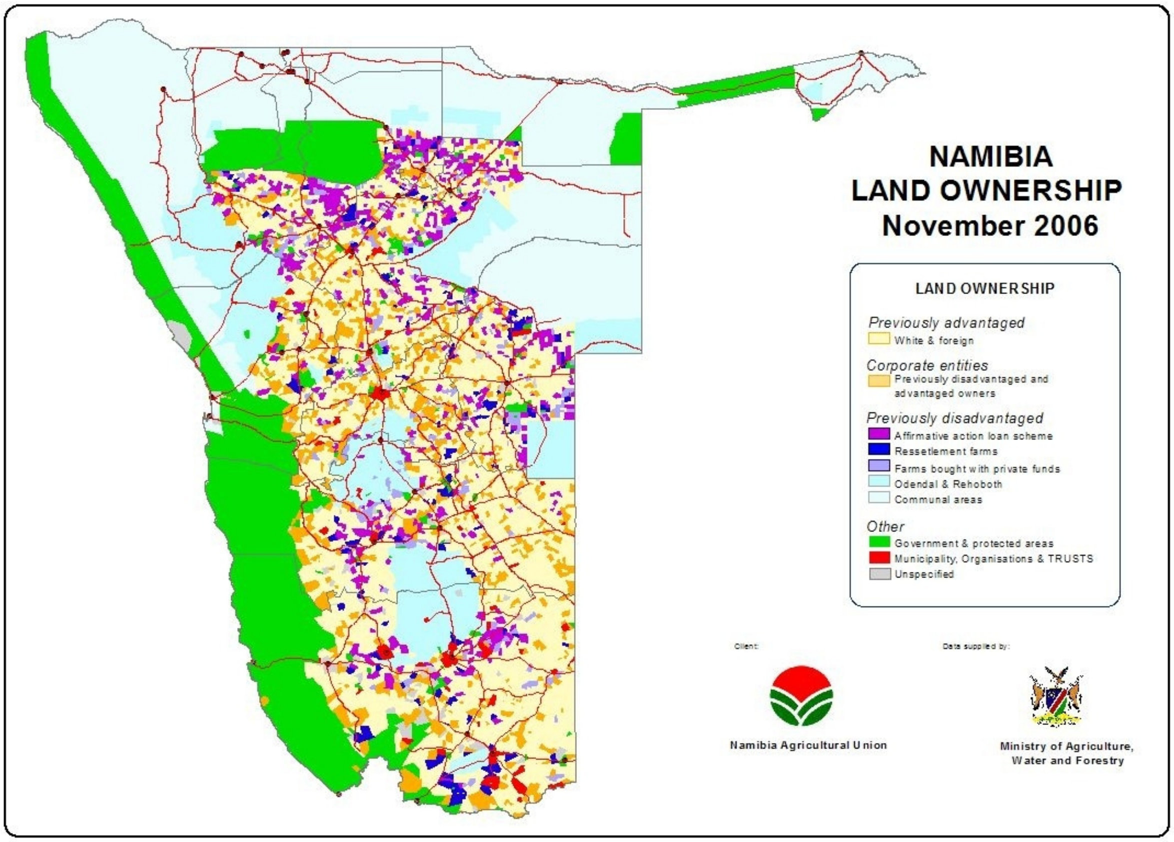


Figure 2.4: Land tenure in Namibia

<u>Gender</u>

In Caprivi female-headed households are relatively more important than compared to the Karas and Hardap regions (Table 2.5). In times where gender inequity plays a role in access to productive resources and income, this adds another dimension to vulnerability amongst small-scale farmers in the Caprivi region. Whilst –at national level- more than half of the male headed household in Namibia (53%) can rely on salaries and wages as their main source of income, this only applies to 36.6 % of female-headed households in Namibia. In comparison with male headed households, relatively more female headed households depend primarily on subsistence farming as their main source of income (25.5 % and 33.7 % respectively)(Republic of Namibia 2006a). The PPA in various regions of Namibia revealed that having access to a salaried job has positive implications in terms of access to productive farming resources for rural households, as a proportion of cash income can be invested in productive means.

Table 2.5: Households by gender of household head (%)

	Female (%)	**Male (%)**
Caprivi	50.0	50.0
Hardap	30.1	69.9
Karas	23.9	71.1
National	*40.5*	*59.5*

Source: adapted from (Republic of Namibia 2006a)

2.6 Literacy and Educational attainment

Literacy rates and education attainment provide information about development at national and regional levels as they reflect people's chances of alternative sources of livelihood and income. The literacy rate of Caprivi and Hardap does not differ substantially from the overall literacy rate in Namibia, but significantly more people in Karas are literate. People in the Caprivi and Karas regions are slightly better of in terms of literacy than the average rural Namibian.

Table 2.6: Literacy rate for population aged 15 and above

	Female	Male	Both sexes
Caprivi	75.9	83.8	79.5
Hardap	81.8	81.1	81.4
Karas	90.9	91.7	91.3
National	*82.4*	*84.0*	*83.2*
Rural	*75.7*	*77.1*	*76.3*

Source: adapted from (Republic of Namibia 2003a)

Educational attainment for the population aged 15 years and above is presented in (Table 2.7), which underlines that it is higher in the Caprivi, Hardap and Karas than in rural areas of Namibia in general. Nevertheless the proportion of people that have never attained secondary or tertiary education is still very low. If these statistics mean anything for the generation currently in school, questions arise as to how easily young people will be able to pursue other livelihood means besides subsistence farming in future.

Table 2.7: Highest level of education attained of the population aged 15 years and above

	No formal education	Primary school	Secondary School	Tertiary qualification
Caprivi	18.2	24.9	51.7	5.3
Hardap	18.0	33.1	45.5	3.0
Karas	8.8	29.9	54.6	5.9
National	*16.7*	*31.7*	*45.5*	*5.9*
Rural	*22.7*	*38.4*	*35.8*	*2.7*

Source: adapted from (Republic of Namibia 2003a)

Currently 42% of the group with no formal education list subsistence farming as their main source of income; 40% of the group with primary education, whilst only 16% and 3% of the groups with secondary/tertiary education depend primarily on subsistence farming as their main source of income (Table 2.8) (Republic of Namibia 2003a).

In connection to the point raised above national and regional education statistics provide a rather worrying picture. The survival rate of learners up to grade 7, the last grade of primary school in Namibia, amounted to 80% in 2003. This means that by the entry of Grade 7, 20% of learners who started their education in Grade 1 have dropped out of the educational system in one way or another. The survival rate up to Grade 10 and 12 in 2003 stood at 57 and 30 percent respectively ((Republic of Namibia 2005b). These last figures underline that more than 40% of earners fail to reach Grade 10 in Namibia and that not even one in three learners who started Grade 1 attains Grade 12. The JSC-examination is a strong selection filter for entry into senior secondary level. Of those learners that actually manage to complete Grade 10 less than half (45%) were capable of passing the exam in 2003. Learners in the southern regions perform better than in the Caprivi; whilst in Caprivi only 41% of learners passed the JSC exam in 2003, in Hardap 55.7 % passed and in Karas 59.7 percent.

Developing human resources is a key consideration in any development process; these figures show how pertinent skills development and education are to reduce dependency on primary resources vulnerable to even slight changes in climatic conditions. This issue was underscored by PPAs in many regions. Participants usually identified the youth as a vulnerable group because of the limited chances to complete a proper education. Thus, it limits the opportunities for young people to find work and move out of poverty (Republic of Namibia 2006b; Republic of Namibia 2007a).

2.7 Employment and main source of income

The Hardap and Karas regions are characterized by a stronger developed wage economy, compared to both the country on average and certainly the Caprivi region, where subsistence farming and small scale enterprises are relatively more important. The high level of dependence of rural dwellers on subsistence agriculture nationally makes Namibia particularly vulnerable to changes in the climate.

The importance of subsistence agriculture in Caprivi is further reflected in its labour force statistics; the subsistence agricultural workers rate, meaning the proportion of employed persons in subsistence agriculture, amounted to 47% in 2001, whereas it remained below 10 percent in Hardap and Karas regions (Republic of Namibia 2003a). The importance of subsistence agriculture in Caprivi implies that relatively few people are unemployed; in 2001 e.g. only 17% of the labour force in the region was unemployed whilst unemployment in Namibia on average stood at 31 percent. In 2001 the unemployment figures of Hardap and Karas were also considerably higher than in Caprivi 2001 (34 and 29 percent respectively).

The vulnerability or rural dwellers was acknowledged by participants to PPAs in various regions. People in the Caprivi e.g. identified that communities with agriculture-based economies were –depending on the location of their villages- highly vulnerable to environmental shocks, such as floods, drought, livestock diseases and pests, as well as human-wildlife conflict. A number of the self-employed business activities in the Caprivi region that serve as coping strategies are also resources based, such as craft making and selling thatching grass and reeds (Republic of Namibia 2006b).

Table 2.8: Households by main source of income, region and rural areas (%)

	Salaries and wages	Subsistence farming	Commercial farming	Pensions	Remittances and grants	Drought/ in kind receipts	Business income	Other
Caprivi	32.5	17.8	0.1	12.9	6.2	5.5	17.0	7.2
Hardap	61.7	4.9	2.9	19.4	4.0	2.2	2.8	1.3
Karas	73.1	4.8	2.2	10.4	2.4	0.8	4.0	1.3
National	*46.3*	*28.9*	*0.7*	*9.2*	*2.8*	*2.4*	*7.1*	*1.6*
Rural	*25.7*	*48.0*	*1.2*	*21.1*	*2.4*	*3.3*	*4.5*	*2.0*

Source: adapted from (Republic of Namibia 2006a)

The vulnerability of an important share of rural people in Namibia is further underlined by the fact that 21 % of them rely on pensions and grants as their main source of income. In this context it is further important to note that more than 5% of the population relies on drought relief and other in kind gifts and donations as the main source of income. Although both pension/grants and drought relief provide an important safety net for many of the poor and vulnerable in the country, the monthly stipends only allow for the access to basic needs and services, but hardly for investment in productive resources that are required to produce sufficient food for a family. Drought relief is moreover only a temporary measure.

According to the PPA in the three regions the regional unemployment rate, although important, is not a proper measure of the vulnerability of households in the region. Rather, the proportion of households with or without access to salaries is relevant. For, it was often implied that when at least one person in a household has access to a salaried job, it is more likely that the family belongs to a wealthier segment of the community. Households without employed family members are relatively more vulnerable to become poorer in the near future, because they are more dependent on primary production and thus on the variable climatic conditions. Hence, although the unemployment rates in the Karas and Hardap region are higher than in Caprivi, which means that more individuals are unemployed, it also appears that a larger proportion of families in these regions have access to salaries or wages (Table 2.8). The latter would imply that on average households in the Karas and Hardap are less vulnerable to climate variability and climate change than households in the Caprivi.

2.8 Health and HIV/AIDS

The impact of HIV/AIDS on the populations of Namibia's regions has grown significantly since the early 1990s when the prevalence rate stood at 4.2% (1992). By 2004 the HIV prevalence rate amongst pregnant women had come down 19.8% after a peak of 22% in 2002. The situation in the Caprivi region is a matter of serious concern to policy makers and health officials in the country, as 43% of pregnant women in Katima Mulilo were infected in 2004 (Republic of Namibia 2004a). The prevalence rate in the southern regions was considerably lower and ranged from 11% in Mariental to 14% and 16% in Mariental and Keetmanshoop.

Table 2.9 HIV-prevalence rate, infant mortality, maternal mortality and malnutrition rates by region

	HIV-prevalence 2004	Infant Mortality 2001		Under 5 Mortality 2001		Underweight children 2000
		F	M	F	M	
Caprivi	43 %	56	62	82	111	18.2 %
Hardap	11 %	60	63	67	74	22.2 %
Karas	16 %	37	56	55	60	13.7 %
National	*19.8 %*	49	55	*64*	*78*	*24.0 %*
Rural	*NA*	*54*	*61*	*73*	*88*	*26.7 %*

Source: adapted from (Republic of Namibia 2004a) and (Republic of Namibia 2003a and 2003b)

The HIV/AIDS pandemic has implications for family structure in Namibia as the number of children that have lost one or both parents has increased substantially over the last two decades. In 2001 a quarter of all households in Namibia had a child below the age of 15 which had lost 1 parent or both parents. The table below reveals that orphanhood affects families in the Caprivi region more strongly than households in the other two regions, where the share of affected households can nevertheless not be ignored. Although the statistics do not reveal this, it implies that the number of child headed households which are vulnerable by definition in the Caprivi region may be relatively higher as well. The comparatively large proportion of households with orphans in Caprivi is most likely related to the high HIV-prevalence rate in the Caprivi. The PPA underscored that taking extra children in a family constitutes a burden of care, which actually makes families more vulnerable. This burden is increasingly difficult to carry by rural households, because it means that their limited resources get stretched. The loss of an adult family member, in particular a male breadwinner, can further be devastating to a household. When a husband dies and the spouse and children are left behind with the responsibility to continue cultivation and cattle raising, many households fail and gradually fall into poverty. Such families are further said to be vulnerable to land grabbing and the remaining women are from time to time faced with unequal inheritance practices (Republic of Namibia 2006b).

Table 2.10: Proportion of households with at least one child below the age of 15 that is orphaned

	Proportion of households with at least one child below the age of 15 orphaned by	
Area	**One parent**	**Both parents**
Caprivi	28.4	5.6
Hardap	16.2	2.0
Karas	15.6	2.0
Namibia	23.9	3.3
Namibia Rural	27.8	3.9

Source: adapted from(Republic of Namibia 2003a)

The health status of the population in the three regions is further reflected by the infant and under 5 mortality rates, as well as malnutrition statistics. In terms of child mortality the Caprivi region performs worse than the other two regions and than Namibia in general. Children in the Karas region appear to be better of on all accounts than children in the other two regions. As far as malnutrition is concerned, the Hardap and Caprivi regions perform slightly better than Namibia on average and than other rural areas of Namibia. The Karas region performs considerably better, which might possibly be related to the fact that the region is more urbanized and has an economy that is more strongly based on wage incomes, rather than subsistence modes of production.

2.9 Access to services

The distance to a shop or market (as in Table 2.11 below) can both serve as a proxy for food security (if considering cash availability) as well as integration in the formal market economy. Yet, in comparing the three regions, geographical factors such as vastness of the respective regions and their population densities also play a role and care should be taken in using these proxies.

Table 2.11: Distance to shop or market (% of households)

	0 - 1 km	**2 – 5 km**	**6 – 10 km**	**11 - 20 km**	**> 20 km**
Caprivi	50.2	35.8	6.7	3.8	3.5
Hardap	53.3	15.9	6.1	6.1	18.5
Karas	67.9	11.4	1.7	1.8	17.0
National	**53.9**	**25.4**	**7.0**	**5.6**	**8.1**
Rural	*36.2*	*29.4*	*11.3*	*9.4*	*13.7*

Source: adapted from (Republic of Namibia 2006a)

Table 2.12: Distance to health facilities (% of households)

	0 - 1 km	**2 - 5 km**	**6 – 10 km**	**11 - 25 km**	**> 25 km**
Caprivi	26.0	40.0	18.0	13.8	2.5
Hardap	30.8	33.0	5.0	10.9	20.3
Karas	47.8	23.0	1.0	2.3	25.2
National	**29.9**	**34.0**	**14.0**	**11.7**	**10.5**
Rural	*12.8*	*28.0*	*22.0*	*19.4*	*17.6*

Source: adapted from (Republic of Namibia 2006a)

In terms of access to shops and government services the situation in Karas is quite different from Caprivi and to a lesser extent Hardap, which likely reflects differences in the degree of urbanization between the regions. Two out of three individuals have access to a shop within 1 km distance in the Karas region, whereas this applies to half of the population in Caprivi and Hardap only. Similarly nearly half of the population of Karas states to have access to a health facility within 1 km distance, whereas this applies to considerably smaller shares of the population in Caprivi and Hardap. A comparatively large proportion of the population of Karas and Hardap further has to travel more than 20 km to a shop, or more than 25 km to a health facility. This is a reflection of the vastness of these regions, which makes it difficult to provide access to government services and shops in each settlement across the region (Republic of Namibia 2006a).

In Caprivi a relatively large share of the population has access to a shop within 5 km distance, reflecting the smaller size of the region and the settlement pattern of the rural population. As a result, access to primary and secondary schools as well as health facilities is usually reasonably good as compared to other regions. Settlements in Caprivi are found along major rivers and along the edge of area that separates the mopane woodlands from the flood plain. The last group of villages is connected by a road. Access to government services such as schools and health facilities is however reported to be constrained in years when the flood plain gets flooded, making the facilities inaccessible. Sometimes facilities can still be reached, but distances that need to be traveled by road in times of flood are seriously increased, or facilities can only be reached by canoe. When children have to go to school by canoe, they are faced with risks of encountering wildlife such as hippos and crocodiles.

2.10 Social organization and capacity

Strong social organization and support networks can be relevant factors in reducing vulnerability at household and community level. It is against this background that social cohesion and social exclusion were research topics during the PPAs in Caprivi, Karas and Hardap regions (Namibia Agronomic Board 2006a; Republic of Namibia 2006b; Republic of Namibia 2007b).

In the Caprivi region participants to the meetings explained that traditional support mechanism were still being practiced, which prevents that poor people suffer from starvation. However tribalism reportedly affected the willingness to work together and live with each other in villages and communities. Allegedly people in power used their position to the benefit of people of their own section of the community, to the detriment of other cultural groups in the community. The San in the western part of the region had the perception that they were socially excluded, as their leader was not sufficiently acknowledged. This accordingly had negative consequences for access to important safety nets such as drought relief and labour-based works, which may be of relevance with increased stress caused by climate change. It was further noted that certain wealthier or powerful people tended to exploit vulnerable groups and individuals in society. Examples were provided of orphans who through pressure of such individuals on traditional authorities had lost their rights to land and other resources, when their parents passed away (Republic of Namibia 2006b).

In the Karas perceptions around social cohesion or exclusion seemed to focus on perceptions on the part of communities of lack of respect, communication and feedback from various authorities and service providers. This was said of municipalities, town councils, regional councilors, employers and government service providers. Inhabitants of informal settlements in Ludertiz and Aussenkehr in particular complained of lack of support of labour unions the ministry of labour. Support of service providers might therefore be a relevant matter to look into under future climatic conditions, which might warrant the need for well-organised, fair and transparent safety nets for vulnerable groups in the region. In addition there were claims of favouratism and nepotism, which was often connected to the arrival from ‘outsiders’ from other regions, who then took jobs. This is also a relevant concern in a region that is relatively urbanized and where people, in the absence of access to land, pasture and livestock, depend on cash sources of income. In addition people in Karas claimed that there was lack of cooperation and unity in many communities, which was reflected by a lack of properly functioning community based organizations (Republic of Namibia 2007b).

As in the Karas region, in Hardap there were a substantial number of accounts of lack of cooperation in communities, weak or non-existent community organizations, or local structures that are dominated by certain powerful individuals. In some cases whole communities depend on such individuals for their survival, as the powerful individual in question is e.g. the owner of the land they use or occupy. As a result people do not dare to speak out their concerns, resulting in voiceless and constrained communication patterns. In addition people reported lack of cooperation and respect between the youth and the elderly and constrained communication and feedback between communities and elected officials and/or service providers (Republic of Namibia 2007b).

2.11 Conclusion

Vulnerability to climate change is not just informed by patterns of climate change and climate variability per se. Socio-economic factors influence the vulnerability of livelihoods, as well as the adaptive capacity of individuals, households and communities. These socio-economic factors may ameliorate or exacerbate current environmental conditions, and may similarly inform the vulnerability of livelihoods to climatic change and climatic variability.

At the national level, population growth influences the vulnerability of the population living in Namibia’s arid and semi-arid environments. The population of Namibia is expected to grow with 66% between 2001 and 2031 according to the medium scenario of the Population Projections, representing an average annual growth rate of 1.7 % over 30 years. Although this is not a very high annual growth rate, the overall increase in population may exacerbate the vulnerability of livelihoods and ecosystems. First of all, the pressure on land and water resources is likely to increase in the more densely populated communal areas in the north-central regions and the Kavango and Caprivi regions, if one assumes that land management practices will not change significantly without specific interventions.

Secondly, although it is not clearly spelled out in the Population Projections, it is expected that increased population pressure will lead to internal migration and a higher rate of urbanisation, as land degradation and constrained access to productive resources will force people to seek opportunities to make a living elsewhere. According to the Population Projections the Khomas and Kavango regions will be affected most strongly by rural-urban migration. In respect of recent trends in the mining sector, it might further be expected that Erongo will benefit from an influx of urban settlers. These migration patterns put pressure on land and water resources and service providers in regions that receive an influx of urban settlers. At the same time it is not guaranteed that the vulnerability of the migrating population is reduced, unless more employment opportunities are created.

Making a living of the land in Namibia is a challenge and local and regional conditions determine the vulnerability of livelihoods amongst other factors. It is a very different challenge in the Caprivi, the Hardap or Karas region. Livestock farmers depending on transhumance and sedentary crop farmers are both vulnerable to climate change, although in rather different ways. Yet, in a marginal environment such as Namibia's all these groups are heavily dependant on the climate as the basis for their livelihoods, and predicted higher temperatures, along with more variability in the rainfall, suggest severe strains on rural existence both in the North and the South of the country. However there are regional differences. In the Caprivi region relatively more people depend on the natural environment for a livelihood than in e.g. Hardap and Karas. Moreover, there are additional risks for those who are living in the flood plain, especially since communities seem to loose traditional adaptation strategies with the establishment of government infrastructure in the flood plain.

Poverty, lack of income and lack of employment opportunities greatly exacerbate the vulnerability of households, because these factors substantially constrain access to productive resources, with negative consequences in terms of food security for those concerned. It also hampers the capacity of households and communities to recover from recurrent shocks. It should be acknowledged however, that this vulnerability to climate change differs for various socio-economic groups in Namibia. Access to capital, land, labor and other factors of production as well as the possibility to pursue off-farm employment and other diversification strategies are very different for various groups in society e.g. commercial farmers, emerging farmers, and elder people in the rural areas, female headed households or full-time vs. part-time farmers. Their respective buffering capacity to deal with climatic shocks differs markedly. There are also regional differences. Communities in the e.g. the Karas and Hardap regions seem to be somewhat less vulnerable than those in the Caprivi, as more people have access employment, which is reflected in the per capita income and the lower incidence of poverty of the respective regions.

In any discussion on vulnerability the impact of HIV/AIDS cannot be neglected. Although the impact of the pandemic is felt in households across the country, the situation in the certain regions (i.e. Hardap and Karas) is relatively more favourable as compared to e.g. the Caprivi region, where the loss of people in the productive ages due to the pandemic has substantially decreased life expectancy and increased the number of dependents and orphans that households have to support. This puts a strain on rural production and productivity, as well as on financial resources, people and support networks and thus exacerbates the vulnerability of the population, in some regions more strongly than in others. The latter also seems to be reflected in the Human Poverty Index for the country and Caprivi in particular (UNDP 2007).

Given the constrained access to productive resources amongst, the level of poverty and the impact of HIV/AIDS on society, it is a further matter of concern that the capacity for social organization and support in communities in various regions of the country appears to be dwindling. According to the PPA community based organizations are often non-existent in rural areas or not very strong. Accounts of lack of cooperation, jealousy, lack of information sharing and miscommunication between factions in communities and between communities, their elected representatives and service providers during the PPA were numerous. Therefore questions need to be raised about the capacity (and interest) of communities and service providers to address vulnerability under prevailing climatic conditions, let alone to deal with the added stress of climate change.

In relation to matters of capacity, it is furthermore indicative that in many regions of the country the youth are considered a vulnerable group, due to the high drop-out and failure rates in the education system. The national pass rates for the Grade 10 certificate underscore that considerable efforts need to be undertaken to realise a knowledge-based economy. As there are substantial regional differences in educational attainment, one's origin seems to affect future opportunities to obtain employment or to move out of subsistence oriented livelihoods. As educational attainment affects the general level of skills and knowledge in communities, the above further suggests that the organizational and adaptive capacity are likely to be constrained in the longer term in various parts of the country.

High rainfall dependency and prevailing natural vulnerability should have led to an inherent greater resilience and preparedness for climate related shocks. The various issues presented in this chapter however underline that the vulnerability and adaptive capacity in Namibia are exacerbated by a number of factors, such as population growth, lack of access to productive resources, poverty and HIV/AIDS, lack of social cooperation/cohesion and the limited educational attainment. In general, given current population densities, population growth projections and land degradation currently experienced in north-central regions, these regions will remain particularly vulnerable to climate variability and change. The interplay of various socio-economic and environmental factors is however regionally specific. This means that the certain regions have become more vulnerable than others, even though the local environmental conditions appear more favourable at first sight. The Caprivi region – as compared to Karas and Hardap- seems to provide an example of this. High levels of poverty (43%) and a high HIV-prevalence rate have exacerbated vulnerabilities in the region. At the same time, as in many other regions, a limited degree of social organization, limited feedback between communities and service providers, low levels of educational attainment and limited perspectives for the youth further hamper the adaptive capacity in the region.

3 Vulnerability of Namibia's wetlands and water resources to climate change

3.1 Introduction

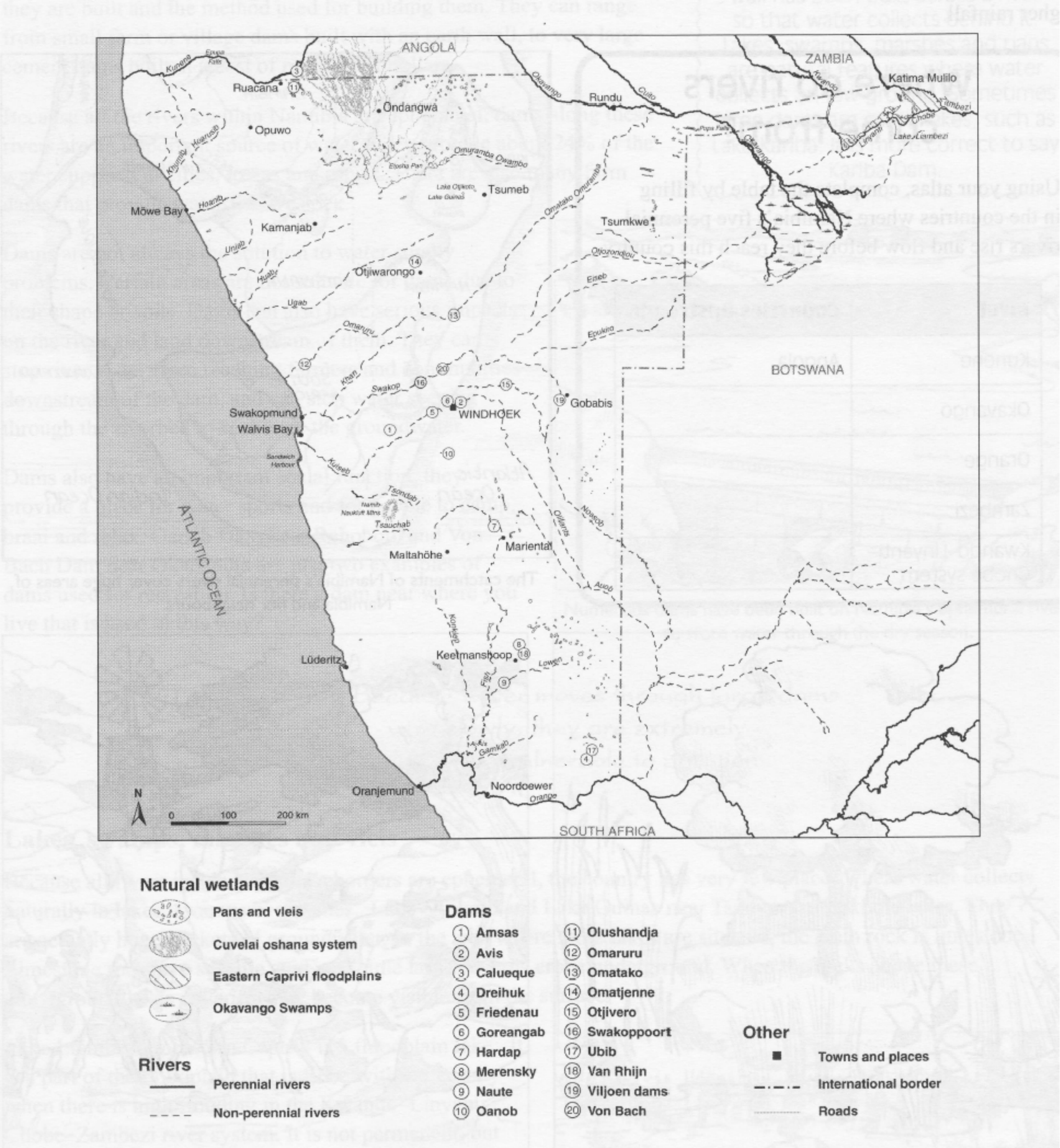
This chapter elaborates the vulnerability of the water sector in Namibia to climate change and climate variability. The chapter starts with an introduction to the different wetlands, such as ephemeral rivers and perennial rivers, springs, pans and lagoons and presents the important ecosystem functions and services of these wetlands (section 3.2). To provide some context to the vulnerability of the water sector to climate change, section 3.3 compares supply and demand for water in Namibia and discusses the growth in demand for water in the next few decades. Section 3.4 presents the impact of climate change on runoff and perennial drainage, as well as historic trends in variability in runoff. As such it serves as an introduction to the discussion of the vulnerability of the water resources and wetlands in Namibia (section 3.5). For the discussion on the vulnerability of wetlands and water resources, a distinction is made between wetlands and rivers in northern Namibia (3.5.2) vs. the coastal zone and the interior (3.5.4). In two sub-sections specific attention is paid to wetlands in the Caprivi (3.5.3) and the Karas.

3.2 Wetlands in Namibia

Wetlands may be broadly defined as areas where there is surface water, shallow marine or terrestrial, permanent or ephemeral (seasonal) (RAMSAR definition cited in (Shaw et al. 2004). Marine wetlands are largely influenced by the sea and will not be affected by changes to rainfall or runoff in Namibia; hence they will not be discussed further. It must be noted, however, that they may be affected by changes in sea level associated with climate change. Terrestrial wetlands are all dependent on and influenced by rainfall, either directly or indirectly. They are among the world's most productive ecosystems and are rich in biodiversity. Apart from providing much-needed water, they also provide a number of essential goods and services to the people and animals living near them.

Namibia is an arid country with an annual average rainfall ranging from almost zero along the coast in the west, to around 650 mm in the extreme northeast (Mendelsohn *et al* 2002). Rainfall is highly variable, unpredictable and patchy, generally falling in the form of short, sharp thunderstorms, with marked run-off. Evaporation exceeds rainfall throughout the country, with the average water deficit being highest in the south east (over 2,300 mm/year) and lowest in the Caprivi (less than 1,300 mm/year), which leads to a water deficit across the country. Whilst evaporation rates are high throughout the country, there are considerable regional differences in the average water deficit. The southern areas, where the water deficit ranges between 2,100 to more than 2,500 mm/annum, loose much more water through evaporation than the north-eastern and coastal areas. The area with high water deficits extends from the south-east to the north-western interior. Due to relatively high level of annual precipitation, the water deficit in the Caprivi region is lowest in the country. As such it contrasts sharply with the Karas region, where the water deficit is the highest (Mendelsohn et al. 2002).

Figure 3.1 Wetlands and dams in Namibia



Source: (Wetlands Working Group of Namibia 2007)

As a result of the low rainfall and high evaporation, the majority of Namibia's wetlands are ephemeral. Most rivers flow intermittently for irregular periods following a rain storm. Ponds, pans and dams fill with water in the rainy season, retaining water for anything from less than a day to a few years, depending on their size and the rainfall that season. The only perennial systems occur along the borders of the country and are fed from higher rainfall in catchments outside Namibia (Figure 1). Shaw *et al* (2004) provide a concise, illustrated summary of Namibia's wetlands. Around 60% of Namibia's population lives near the major wetlands, with the highest population density along the perennial Okavango River (Heyns *et al* 1998).

3.2.1 Perennial wetlands and their services

Perennial wetlands have a continuous source of moisture, although the amount of water and extent of inundation can vary considerably from month to month and year to year. With the exception of the Karst sinkhole lakes, Guinas and Otjikoto in the Tsumeb/Otavi area, small spring-fed streams, and manmade impoundments, Namibia's only perennial wetlands are the rivers which form the northern and southern borders of the country, with their associated floodplains, swamps/marshes and mouths/estuaries. All of these have their headwaters in areas of higher precipitation outside Namibia.

3.2.1.1 Perennial rivers

These include the Kunene in the northwest, the Okavango, Kwando/Linyanti and Zambezi/Chobe in the northeast, and the Orange/Gariep in the south. All are internationally shared rivers, that form the northern and southern borders of Namibia. The Kunene is shared with Angola , the Okavango with Angola upstream and with Botswana downstream, eight southern African countries share the Zambezi system and the Orange River is shared with Lesotho and South Africa upsteam.

The first four systems have their headwaters in the highlands of Angola and Zambia, where rainfall is much higher than in Namibia.

The Kunene enters Namibia at Ruacana and flows westwards along the border between Angola and Namibia into the Atlantic Ocean. At Ruacana it is impounded for hydroelectricity, and as a result the water is released in pulses. Water from Calueque Dam on the Kunene River is transferred into the Cuvelai River Basin to supply many towns in the central north, including Ondangwa and Oshikati via a network of canals and pipelines. Since the lower portion of the Kunene River flows through an arid area, it forms an important linear oasis for riparian vegetation and wildlife. The human population using the river is not large and few people depend directly on the river for natural resources. Tourism to the river provides an income for many people. The mouth forms a very important wetland for various fish species, wading birds, marine turtles and a freshwater terrapin, as well as invertebrates such as the large freshwater prawn, *Macrobrachium vollenhovenii,* and the freshwater oyster, *Etheria elliptica*. The river is threatened by the potential construction of another dam for hydroelectricity.

The Okavango (Kubango in Angola), with its tributary, the Cuito, drains from Angola, flows along the Namibian border and then southwards to the inland delta in Botswana. Although Namibia only has 5% of this system (Beekman et al. 2006), with its extensive floodplains, it has numerous habitats for plants and animals and a high biodiversity (Bethune 1998). The many largely poor people along the Namibian stretch of the river, dependent on the river and floodplains for water and natural resources, are extremely vulnerable to environmental change. The Okavango delta in Botswana is the largest RAMSAR[3] wetland in the world, incorporating 4% of the basin (Beekman *et al* 2006). It is a highly dynamic system, dependent on the seasonal changes in inundation from the north. The ecological richness of the swamps depends on the nutrient-poor water that promotes the growth of papyrus and on the supply of sandy sediment. Lack of development along sections of the river has allowed it

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[3] RAMSAR site – The Convention on Wetlands of International Importance was signed in the town of Ramsar in Iran in 1971. The main aims are to prevent the loss and degradation of wetlands worldwide and to ensure that they are used wisely and sustainably, while conserving their biodiversity values and ecosystem services.

to retain a relatively pristine nature, with a high diversity of fauna and flora. But habitat destruction is increasing at a rapid rate, on both the Namibian and Angolan sides of the middle section and in the panhandle section in Botswana. Tourism in the area is increasing, with lodges along the banks offering fishing and birding. The Popa Falls and Mahango National Parks have preserved stands of riparian forest with a high diversity of woody plants and birds, as well as game species including elephants, hippos, lion, buffalo, giraffe and lion. Various antelope species include rare roan, sable, waterbuck and sitatunga antelope.

The Kwando drains from Angola southwards between east and west Caprivi into the Linyanti / Lake Lisikili system, which forms the boundary between Namibia and Botswana. This is an important riverine/marshy wetland system providing a habitat for fish, birds and wildlife in the Mamili National Park. Mudumu National Park is situated a bit further upstream on the Kwando River. Because the Linyanti connects up with the Zambezi system via Lake Liambezi and the Chobe River in wet years, it is regarded as part of the Zambezi Basin, which is the largest in southern Africa (Beekman *et al* 2006). The Zambezi has its headwaters in the highlands of Zambia, flows westwards and then southwards through Angola, then eastwards towards the Indian Ocean. It forms part of the northern boundary between the Caprivi and Zambia for a short distance (1% of the basin), but is an important source of natural resources for this short distance. Tourism is important along both the Zambezi and Kwando Rivers. The Chobe is fed from floodwaters from the Zambezi and is shared with Botswana. Chobe National Park is an important tourist destination on the Botswana side of the river.

The Orange River (Gariep in South Africa) receives its water from snow melt in Lesotho and rain water from Lesotho (approximately 2 000 mm per annum) and South Africa. It is a highly regulated river with numerous large impoundments upstream of the Namibian section. As a result, only half or less of the annual runoff reaches the mouth (Beekman *et al* 2006). In Namibia, which has about 25% of the catchment (Beekman *et al* 2006), the river flows through a deeply incised valley without any significant floodplains. Because of the rocky nature of the substrate and lack of floodplains in the Namibian section, the vegetation cover and diversity of the river is low. The river banks are lined by trees dominated by *Salix capensis* and *Rhus pendulina,* with periodic reed beds and other smaller shrubs, but very little emergent vegetation. A total of 24 fish species has been recorded for the whole basin of which seven are endemic (Revenga *et al* 2000 in Beekman *et al* 2006). The river mouth/estuary is a RAMSAR site and a very important bird breeding and over-wintering site for migrant birds. Since 1995 this site has been included in the Montreux List, due to degradation related to mining activities near the river mouth. Due to the aridity of the area, few people live directly along the river banks. A large irrigation scheme at Aussenkehr provides work either directly or indirectly for a large seasonal population of migrant labour and satellite small industries, all of which are dependent on the river for water and its other limited resources (C. Roberts, pers. comm.). Mining along the lower reaches of the river and at the mouth extracts large quantities of water, and the impact of the staff on the natural resources is high (C. Mannheimer, pers. comm.).

Within Namibia, the Orange has one major tributary, the ephemeral Fish River, with its numerous tributaries. The rocky substrate and the sparse vegetation in the catchment provide little resistance to water flow across the landscape and hence the runoff into the Fish River is very high in relation to rainfall.

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3.2.1.2 Sinkhole lakes and artesian springs

The only permanent natural wetlands that are entirely within Namibia are the sinkhole lakes Otjikoto and Guinas, the subterranean lakes in Aigamas and Dragon's Breath Caves, and pools and streams associated with springs and seeps. These are all dependant on groundwater and runoff from rainfall within Namibia. The lakes and caves are mostly confined to the Karstveld area of Otavi, Tsumeb and Grootfontein. They do not support much vegetation, apart from a few *Ficus* and other trees that are able to tap the groundwater. There are fish, including the endemic Otjikoto tilapia, *Tilapia guinasana* and the endemic blind cave catfish, *Clarias cavincola*. As they are situated on private land, they are to some extend protected. Otjikoto lake supports a small tourist attraction.

Springs and seeps can be found all over Namibia, being most numerous in the Karst areas, where they may occur on hill sides. Elsewhere they are generally associated with ephemeral rivers and drainage lines. These vary in size and strength from an intermittent oozing of moisture from a rock fissure to large pools and streams fed by strong springs. Some of them, such as Gross Barmen at Okahandja and Ai-Ais in the Fish River are geothermal. These springs support a limited amount of marginal vegetation, which is not exploited by humans. The water is generally an important source of moisture for wildlife and livestock in arid areas. Gross Barmen and Ai-Ais are tourist attractions, the latter being in a National Park.

The amount of runoff, extent of water abstraction and degree of bush encroachment all have an effect on springs. Increased bush in certain areas is sucking up groundwater, which lowers the water table and affects the amount of water pumped to the surface by springs. For example, Frank Bockmuhl (pers. com. to S. Bethune) cleared an area of bush and a spring which had not flowed for 20 years flowed again.

3.2.1.3 Man-made lakes and impoundments

Man-made dams are scattered throughout the country – both the 12 large state impoundments managed by NamWater or the Department of Water Affairs, as well as many smaller farm dams. Most farm dams are ephemeral, but some of the larger ones may retain water for more than one season. All are habitats for fish, amphibians and birds, and provide water for stock and wildlife, particularly the large state dams. Because of the barren drawn down zone and the often rocky nature of the shores of most dams, none is able to support any marginal vegetation. No people are living directly off the resources of these dams. Von Bach, Hardap, Naute and Oanab dams provide recreation for Namibians as well as tourists.

3.2.1.4 Services and goods provided by perennial wetlands

The perennial rivers and their associated wetlands are very important in providing breeding, feeding and nursery areas for a variety of fish, frogs and other aquatic species. They also support aquatic plants such as water lilies, sedges, reeds and thatching grasses, which provide food, traditional medicines and materials for hut construction and craft. The aquatic plants provide varied habitats for birds, which in turn attract tourists. Fish provide a food source for the local inhabitants, as well as recreational fishing for tourists. Water from the river is used directly from the river for human and livestock consumption, as well as for irrigation. Riparian trees provide shade and shelter, building materials, firewood, as well as fruit and habitats for birds, and nectar for bees.

Services provided by wetland vegetation include control of flooding and erosion and improvement of water quality. Plants such as papyrus filter pollutants and recycle excess nutrients. Filter-feeding invertebrates and bacteria help with the decomposition of dead plant and animal matter, thereby adding essential nutrients to the system. Wetlands are also important as carbon reservoirs, reducing the levels of carbon dioxide in the atmosphere (Shaw *et al* 2004).

A hazard of these wetlands is that the floodplain pools and slow-flowing vegetated river margins provide suitable habitats for disease vectors, such as the snail carriers of bilharzia and the mosquito vectors of malaria. Both these diseases are a major problem in the northeast. DDT is sprayed in homes alongside the Okavango river by the Ministry of Health each season to control malaria.

In the dry season, the dry floodplains provide grazing for wildlife and livestock, as well as fertile soil for crop production and vegetable gardening or mulapo farming.

In order to sustain these resources, it is essential that the rivers remain perennial, and that the seasonal floods continue to bring the water and nutrients needed by the plants and animal that depend on them.

3.2.2 Ephemeral wetlands and their services

By far the majority of wetlands in Namibia are seasonal, and scattered throughout Namibia (Bethune 1998). Generally these wetlands are dry for the major part of the year, but this is highly variable. At times they may remain dry for a number of consecutive years, while at others they may flow one or even several times a year and in exceptional years some may have stretches of water for a year or more following very good rains. The main threat to ephemeral rivers systems is the construction of both state and farm dams that cut off the downstream flow of water and nutrients. Traditionally the state dams are designed to hold three years worth of inflow or 3 times the mean annual runoff, this can mean no flow downstream for up to a decade. Namibia is one of the few countries in the world that constructs water supply impoundments on ephemeral rivers.

3.2.2.1 Cuvelai/Etosha system

The most important ephemeral system from a human perspective is the Cuvelai delta system in the central north, which is home to approximately 25% of Namibia's population (Mendelsohn *et al* 2000). Seasonal floodwater from Angola flows southwards through a series of natural channels and pools (*oshona*). This wetland is of vital importance for the people of the area as it provides water and nutrients for people, livestock and crops. It also brings fish, which are an important source of protein. Aquatic plants abound in the warm, nutrient-rich water and are used as food and medicine, as well as for building material and craft. Groundwater supporting shade and fruit trees is replenished by the annual floods. The flooding of the oshana is augmented by local rainfall in the area. Until recently the people of the area depended entirely on this seasonal floodwater and on hand-dug wells in the dry season.

Associated with this system is Lake Oponono and Etosha Pan, Namibia's largest inland wetland. Roughly once every four years, a high flood (*efundja*) causes water to reach further south and once every seven or ten years this may extend into and fill the Etosha Pan. These two pans fill with water irregularly, but when they do, they provide food for wading birds. Etosha is one of only two places in southern Africa where flamingos breed and as a result is an important RAMSAR site. The pan and springs around the edges support abundant wildlife, making this the most important tourist destination in Namibia.

3.2.2.2 Ephemeral rivers

Namibia is criss-crossed with extensive seasonal drainage lines. Trees and shrubs are often found along the banks of these water courses, and grasses may grow in sandy river beds after floods. These provide a limited amount of food for livestock and game.

The most important of these are the westward flowing rivers in the northern half of the country (Jacobson *et a*l 1995, Jacobson 1997). They act as linear oases, draining the higher rainfall plateau and flowing through the arid Namib Desert. They generally have a subterranean aquifer that is recharged from the seasonal flow, and which provides water to the riparian woodlands that grow within the river beds and along the banks. The most important tree species are *Faidherbia albida* and *Acacia erioloba* which provide food for game and wildlife, shade, shelter and nesting places for birds and many other small animals. Growth of the adult trees and recruitment of young trees is dependent on regular flooding of these rivers (Seely et al. 1981), (Ward and Breen 1983) (Moser 2005). Other species of trees include *Ficus sycomorus, Ficus cordata, Euclea pseudebenus,* and *Tamarix usneiodes,* and *Hyphaene petersiana* in the more northern rivers.

The rivers provide a source of water in the form of wells for the people living along them, as well as an important source of water, food and shelter for wildlife and domestic stock.

In places in some of the rivers, permanent springs support dense reed beds as well as sedges and other plants, which are used for construction and mat making. The springs are an important water source for game and stock.

From the Ugab northwards, these linear oases support relatively large numbers of game, and act as corridors from the more mesic interior of the country to the coast. Game includes elephants, rhino, giraffe, springbok, oryx, steenbok, kudu, klipspringer, baboons, ostrich, leopards, with the occasional lion or cheetah. The game, as well as the spectacular desert scenery, is an important tourist attraction.

The Fish River is the most important southward flowing ephemeral river, which, together with its tributaries, drains a large part of southern Namibia into the Orange River. (Some sections of this river may retain water all year round). There are two state dams on this system in Namibia. Hardap is the largest impoundment in Namibia which provides water to the town of Mariental and to an irrigation scheme downstream of the dam. Naute is a smaller dam on the Löwen River, a tributary of the Fish downstream of Hardap, that provides water to Keetmanshoop and to a date plantation. There are no large alluvial aquifers along the Fish River, thus only limited riparian growth of trees and some very localised reed beds, mainly in the channel downstream of Hardap Dam. Due to recent floods in this area there are now attempts to remove these reeds below the dam. This river system does not support much game, and few people are directly dependent on the river for a livelihood. Downstream of Hardap dam there are some large commercial irrigation schemes that are dependent on water from the dam. The Fish River Canyon in the lower reaches of the river falls within a national park, and is a popular hiking trail. The hot spring and resort at Ai-Ais have already been mentioned.

The Nossob, Olifants and Auob Rivers draining south-eastwards from the central plateau, flow out of Namibia along the Botswana border and into South Africa. They used to flow into the Orange River, but haven't done so in living memory and are regarded as fossil drainages. In places they support riparian woodlands, consisting mainly of *Acacia karroo, Acacia erioloba* and the seriously invasive alien, *Prosopis* spp.

3.2.2.3 Pans

The Nyae-nyae pans system of former "Bushmanland", in the Tsumkwe district, comprise a number of seasonal pans that are important for people, livestock, game and tourism in that area. Some are calcareous salt pans, supporting invertebrates and wading birds, but no vegetation. Many of them are vegetated clay pans with aquatic plants that may be used by the local people. A number of pans in the "pannetjiesveld" around Grootfontein and in the south are not vegetated, but provide temporary water points for livestock and game, and feeding grounds for wading birds. These are dominated by invertebrates, predominantly crustacea, that are adapted to completing their life cycles rapidly while the pans are inundated. They have resistant eggs that can remain dormant for a number of years, before the next inundation.

Although all these ephemeral systems described above are adapted to withstanding long dry periods, it is essential that they are recharged from time to time. In both perennial and ephemeral rivers, the timing, duration and extent of flooding are all important factors for maintaining the system in its present equilibrium.

3.3 Water supply and demand in Namibia

Although in general Namibia is characterized by a water deficit, it is relevant to have an overview of the quantitative aspects of water supply and demand to put the vulnerability of Namibia's wetlands and water resources in context. Namibia abstracts about 660 Mm³ of freshwater from groundwater resources, perennial and ephemeral rivers on an annual basis, whilst there is an infrastructural capacity to store and supply 422.5 Mm³ of water (Christelis and Struckmeier 2001; Republic of Namibia 2006e). Actual demand in 2001/02 amounted to about 274.7 Mm³, as compared to 235.8 Mm³ of water in 1997/98. The volume of water used has risen by 15 % over the 5-year period since 1997/98. Close to 40% of the total supply was provided by groundwater resources and more or less 30% each by perennial and ephemeral rivers. The relative shares of groundwater, perennial river water and ephemeral river water vary, depending in part on rainfall and inflows into dams. The share of perennial river water appears to be increasing fairly steadily, reflecting the growth of irrigated agriculture along the perennial rivers. Recycled water, although locally important, has not provided more than 1% of freshwater in any year between 1997/98 and 2001/02 (Republic of Namibia 2006e).

Table 3.1 Water use in Namibia in 1997/98 and 2001/2002

	Annual Supply	Capacity of Installed Infrastructure	Use 1997/98		Use 2001/02	
	(Mm^3)	(Mm^3)	(Mm^3)	%	(Mm^3)	%
Ephemeral Rivers	200	100	71.0	30.1%	82.9	30.2%
Groundwater	300	150	96.3	40.8%	104.7	38.1%
Perennial Rivers	150	170	66.2	28.1%	85.9	31.3%
Reclaimed water	10	7.5	2.3	1.0%	1.2	0.4%
Total	**660**	**422.5**	**235.8**	**100%**	**274.7**	**100%**

Source: after (Christelis and Struckmeier 2001; Republic of Namibia 2006e)

The agricultural sector is the major user of water in Namibia; around 75 % of all water in the country is consumed by this sector (Table 3.2). The commercial agricultural sector consumes nearly half of all water in the nation and a quarter is used by communal farmers. In 2001/02 80 % of the demand for water in commercial agriculture was accounted for by irrigation requirements and 20 % by livestock. In communal agriculture 53 % of water demand was needed for irrigation and 47 % for livestock. (Republic of Namibia 2006e). The relative importance of irrigated farming for the agricultural sector is underscored by the fact that between 1995/96 and 2002/03 the area under irrigation rose from 6,673 ha to 9,847 ha, an increase of 48 percent. Demand for irrigation water grew at nearly similar rates (44%) from 110 to 159 Mm^3, which on average amounts to half of the national water demand.

Table 3.2 Water use by sector, Namibia in 1997/98 and 2001/02

	Water Use			
Economic Sector	**Volume (Mm^3) 1997/98**	**% 1997/98**	**Volume (Mm^3) 2001/02**	**% 2001/02**
Agriculture	169.33	71.8	202.03	73.6
Commercial Agriculture	*109.59*	*46.5*	*124.95*	*49.1*
Communal Agriculture	*59.74*	*25.3*	*67.08*	*24.4*
Fishing	0.03	0.0	0.69	0.3
Mining	8.73	3.7	9.13	3.3
Manufactering	5.96	2.5	6.64	2.4
Services	7.01	3.0	7.92	2.9
Government	14.21	6.0	14.15	5.2
Households	30.15	12.8	33.60	12.2
Rural	*8.48*	*3.6*	*9.15*	*3.3*
Urban	*21.68*	*9.2*	*24.46*	*8.9*
Other	0.4	0.2	0.5	0.2
Total	**235.82**	**100**	**274.67**	**100**

Source: After (Republic of Namibia 2006e)

The second most important group of water users is domestic users; in 2001/02 households accounted for 12.2 % of water demand in Namibia. Urban households, comprising only a third of the population in 2001 (Republic of Namibia 2003a), were responsible for 70 to 75 % of total domestic water demand (Republic of Namibia 2006e). Government and services accounted for about 8 percent of water demand, whilst mining and manufacturing used nearly 6 percent of all freshwater resources in Namibia.

The mining industry, one of the major sectors of the Namibian economy, is not a significant user of water. This is due to the fact that diamond mining has moved increasingly to offshore mining sites, resulting in the extensive use of seawater rather than freshwater in the production process. In 2001/02 three mines together accounted for 73% of mining water use: Navachab (12%), Rosh Pinah (16%) and Ongopolo/Kombat (45%).

As Namibia is a water-scarce country efforts have been undertaken to express the socio-economic benefits that different sectors and users generate as a measure per m^3 of water used, the so-called water productivity. In marked contrast to its demand for water, water productivity in the agricultural sector is far below average (Table 3.3). The fishing industry and diamond mining are among the sectors with the highest water productivity in the country, whilst water productivity in government and the service sector, comprising trade, hotels and restaurants (tourism), is also above average. As far as the diamond mining is concerned, the water productivity of the sector is partially explained by the fact that until 2001/02 a fairly large number of diamond mining companies relied on seawater for their production activities, rather than freshwater. The same applies to the fishing industry. Water productivity for the mining sector at large is generally lower, and may have changed since 2001 with the opening of Skorpion Zinc mine (Republic of Namibia 2006e). It may further change in the future with the opening of other mines that do not rely on seawater for production activities.

Table 3.3 Contribution of freshwater resources to National Income by economic sector in 2001/02

Economic Sector	**% of water used**	**GDP (N\$ Million)**	**Value Added (N\$ / m^3)**
Agriculture	73.6	918	4.5
Commercial Agriculture	*49.1*	*623*	*4.6*
Communal Agriculture	*24.4*	*296*	*4.4*
Fishing	0.3	649	939.0
Mining	3.3	1,162	127.2
Other mining		*324*	*39.6*
Diamond mining		*838*	*891.1*
Manufacturing	2.4	1,697	260.6
Utilities	0.1	229	998.4
Construction	0.1	510	1850.7
Services	2.9	4,373	551.9
Trade		*1513*	*775.5*
Hotels & Restaurants (Tourism)		*298*	*164.8*
Government	5.2	3,313	234.2
VALUE ADDED			
Average for all sectors			***57.2***
Average, excluding agriculture			***203.8***

Source: after (Republic of Namibia 2006e)

The national resource accounts further substantiated that water productivity has slightly declined from N\$ 58.4/m^3 in 1997/98 to N\$ 57.2/m^3 in 2001/02. The decline is attributed to the rapid expansion of irrigated farming and to the decline of water productivity in communal production, as a result of which overall agricultural water productivity declined from N\$ 5.4/m^3 to N\$ 4.5/m^3 during this period. In non-agricultural sectors water productivity rose from N\$ 193.3/m^3 to N\$ 203.8/m^3 in the same period, an increase of 5.4% in water productivity (Republic of Namibia 2006e).

Against a background of water scarcity in the country, the water productivity statistics raise questions about the utility of irrigated farming, especially if one considers the environmental risks associated with irrigation.

3.3.1 Growth in water demand towards 2015

Table 3.4 summarises water demand by sector for 1999, 2005 and 2015 (Windhoek Consulting Engineers 2000). The most obvious increase in demand for water is expected to be related to the anticipated growth in demand for irrigation water in the agricultural sector. Between 1999 and 2005 an increase of 120.6 Mm³ in total water demand was expected, mostly due to increased irrigation requirements. (Windhoek Consulting Engineers 2000) further expected that there would be relatively low increases in domestic demand in urban and rural areas due improved water demand management practices, whilst a reduction in wastage of water for livestock was expected to have resulted in lower demand for livestock by 2005. Even by 2015 stock water demand is not expected to have increased significantly. It is noteworthy though that by 2015 total anticipated demand of 555 Mm³ will have surpassed the capacity of the currently installed water infrastructure (422 Mm³) by approximately 130 Mm³, whilst the expected water demand for 2005 nearly equaled the capacity of current infrastructure.

Table 3.4 Growth in Namibian water demand by sector from 1999 to 2015 (in Mm³)

Sector	**Consumption 1999**	**% of Total (1999)**	**Consumption 2005**	**Consumption 2015**
Urban (all inclusive)	62.6	21.1 %	66.4	83.5
Rural	5.7	1.9 %	5.8	5.7
Agriculture (irrigation)	135.9	45.8 %	239.1	342.3
Agriculture (stock)	77.1	26.0 %	73.6	80.5
Mines	13.4	4.5 %	29.8	40.0
Tourism	2.3	0.8 %	2.7	3.5
Total	**296.9**	**100.0 %**	**417.5**	**555.4**

Source: (Windhoek Consulting Engineers 2000)

3.3.2 Municipal water supply and demand

Municipalities were responsible for nearly a quarter (24%) of water use in Namibia in 2001/02. Municipal water use grew from 60.3 Mm³ to 65.7 Mm³ between 1997/98 and 2001/02, a growth of 9 percent. Households are the single largest user of municipal water, accounting for 39% of municipal demand in 2001/02. Efficient use of water in municipal water supply encounters major problems as a quarter of all municipal water is lost or not accounted for. In fact, there are 12 towns or local authorities with water losses and unaccounted water ranges from 20% - 39% of municipal supply. There are another 15 local authorities where water losses and unaccounted water comprise 40% - 59% of water supply and a few towns where it even exceeds 60% of water supply. Water supply of all these local authorities together accounts for 37% of total municipal water supply (Republic of Namibia 2006e). This means that substantial gains can be made by improved water demand management measures.

Table 3.5 Towns with non-revenue water of 20% or higher in 2001/02

Towns	Loss and unaccounted water as a % of water supply	Share of national municipal water supply
Katima Mulilo, Ondangwa, Kalkrand, Tsumeb, Mariental, Ongwediva, Outjo, Oranjemund, Okakarara, Henties Bay, Oshakati, Karibib	20% - 39%	21%
Berseeba, Maltahohe, Bethanie, Gochas, Witvlei, Usakos, Aranos, Karasburg, Otavi, Koes, Leonardville, Aroab, Keetmanshoop, Arandis, Rehoboth	40% - 59%	11%
Uis, Opuwo, Tses, Gibeon, Stampriet, Kamanjab, Rundu	> 60%	5%

Source: (Republic of Namibia 2006e)

3.4 Impact of climate change on runoff in Namibia

This section elaborates the impact of climate change on runoff in Namibia. In this regard a distinction is made between the impacts on perennial rivers and ephemeral rivers. As far as the impact on runoff in ephemeral rivers is concerned, the discussion presented in section 3.4.3 relies on detailed rainfall-runoff modelling undertaken in collaboration with the Department of Water Affairs. Due to paucity of input data and other resource constraints similar modelling could not be undertaken for the impact of climate change on runoff in perennial rivers in the North of Namibia. As a consequence, to obtain an understanding of the impact of climate change on runoff in perennial rivers, this report relies on references to other studies. The discussion in the next section starts with an analysis of historic trends in variability of river flow (section 3.4.1) and is followed by the projected impacts of climate change on runoff and drainage in perennial rivers (section 3.4.2).

3.4.1 Historic trends in climate variability and perennial drainage

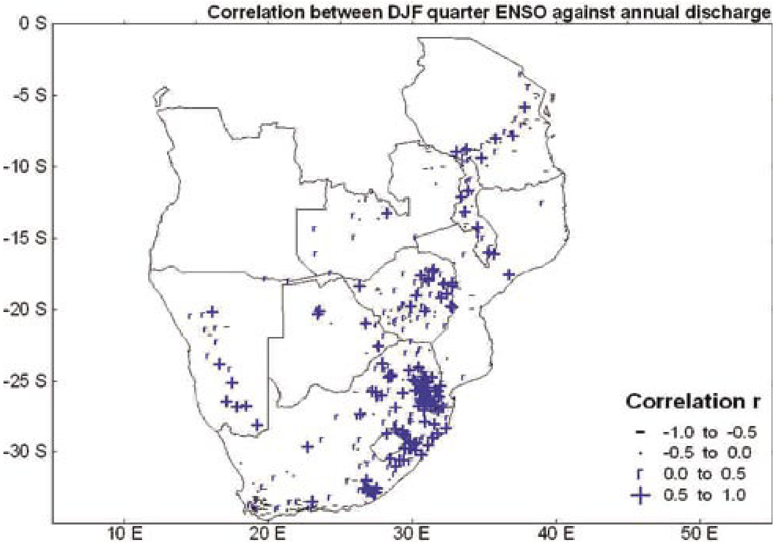
Perennial rivers in the north depict a typical pattern of one or two seasonal flood peaks with otherwise normally steady flow throughout the year. The physical features of terrains to the north of Namibia, where the Kunene, Kavango and Zambezi rivers have their headwaters are such that river flow is not only dependent on a direct surface runoff response. It also includes a delayed flow component, due to storage in swamps and floodplains in the upper parts of the drainage basins (Van Langenhove et al. 1998). In terms of understanding the impact of climate variability and climate change on stream flow in perennial rivers along Namibia's northern border, in particular in the Caprivi, changes in patterns of rainfall over Angola and in particular western Zambia are important factors to consider (Van Langenhove 2007). This section starts with an analysis of trends in climate variability and runoff and continues with the impact of climate change on perennial river flow.

The historic record reveals that river flow in the Zambezi and the flow of water into the Caprivi wetlands are influenced by annual variation, as well as long term modulation in discharge volumes. The long-term record of the Zambezi River at Victoria Falls, nearby the Namibian border, reveals four periods with significantly different average seasonal flow volumes (Van Langenhove et al. 1998; Republic of Namibia 2006e):

1. 1907/08 to 1923/24: 24,300 Mm3/a
2. 1924/25 to 1945/46: 30,000 Mm3/a
3. 1946/47 to 1980/81: 44,000 Mm3/a
4. 1981/82 to 1996/97: 23,300 Mm3/a
5. 1997/98 to 2001/02: 35,034 Mm3/a

Similar variations and especially the marked decline from the early 1980s to the mid 1990s can be found in the records for the Kunene, Kwando and Kavango rivers (Mendelsohn and Roberts 1997). For the change in flow volume in the early 1980s no climatological and infrastructural reasons were available and thus the modified river flow regime was attributed to changes in land use and increased vegetation cover that were related to less intensive use of the land during internal conflict situations and liberation struggles (Van Langenhove et al. 1998). Accordingly, the modified flow regime led to generally dry conditions and low river levels in the Caprivi wetlands between 1981/82 and 1996/97. This pattern was only broken by a large flood in 1989, coinciding with a la Niña year.

Figure 3.2 Correlation between December - February quarter ENSO phenomena and annual runoff in Southern and Eastern Africa



Source:(Alemaw and Chaoka 2006)

(Alemaw and Chaoka 2006) provide a different perspective on the low flow regime in rivers in Southern Africa since the mid 1970s. They explain that the low flow records of major river basins in Southern Africa in the period between 1976 and 1995 can be attributed to the more frequent occurrence of warm ENSO phenomena or El Niños; before the mid-1970s El Niño seems to have occurred with regular frequencies at intervals of about 3 to 7 years. But between 1976 and 1995 alone, there have been about 9 El Niños. In their study on runoff in 502 rivers in Southern and Eastern Africa in the period 1950-1998 the authors found a relation between the December – February ENSO index and annual runoff in 65% of the rivers. In fact the variability in annual flow revealed a strong correlation (r>0.5) with the December – February ENSO index, with more than 25% of the variance in annual discharge being accounted for by the El Niño event, for 150 rivers. Another 174 rivers had a weaker but positive correlation. This means that below-normal rainfall in the region during El Niño years, leading to reduced discharge of rivers in particular in southern parts of Zambia, Namibia, Mozambique and the lowveld of South Africa, is one of the major contributors in the year-to-year variability of runoff in the region. This substantiates the idea that the decline in river runoff since the mid-1970s is associated with a high frequency of drought-related ENSO phenomena. It further suggests that the recent climate trends in Southern Africa are characterized by a higher degree of variation in annual runoff.

3.4.2 Impact of climate change on runoff and drainage in perennial rivers in northern Namibia

In a study on the impact of climate change on runoff in perennial rivers in Africa, (De Wit and Stankiewicz 2006) elaborate the consequences of changes in the pattern of rainfall on perennial drainage for areas with different rainfall regimes. In this regard the authors make a distinction between regions with average annual rainfall of < 400 mm/annum, areas with annual rainfall between 400 mm and 1000 mm and regions where precipitation of more than 1000 mm per year can be expected. The authors focus their attention on areas with regimes between 400 – 1000 mm, called the 'unstable' regime, because changes in precipitation over areas characterised by such rainfall regimes would result in serious changes in runoff. Areas receiving less than 400 mm per year are of less interest as they have no perennial drainage, but are characterised by ephemeral rivers. Major parts of the interior of Namibia are characterised by the rainfall regime of less than 400 mm, but the Caprivi and western Zambia are regions which fall in the rainfall regime of 400 – 1000 mm, and may thus be affected.

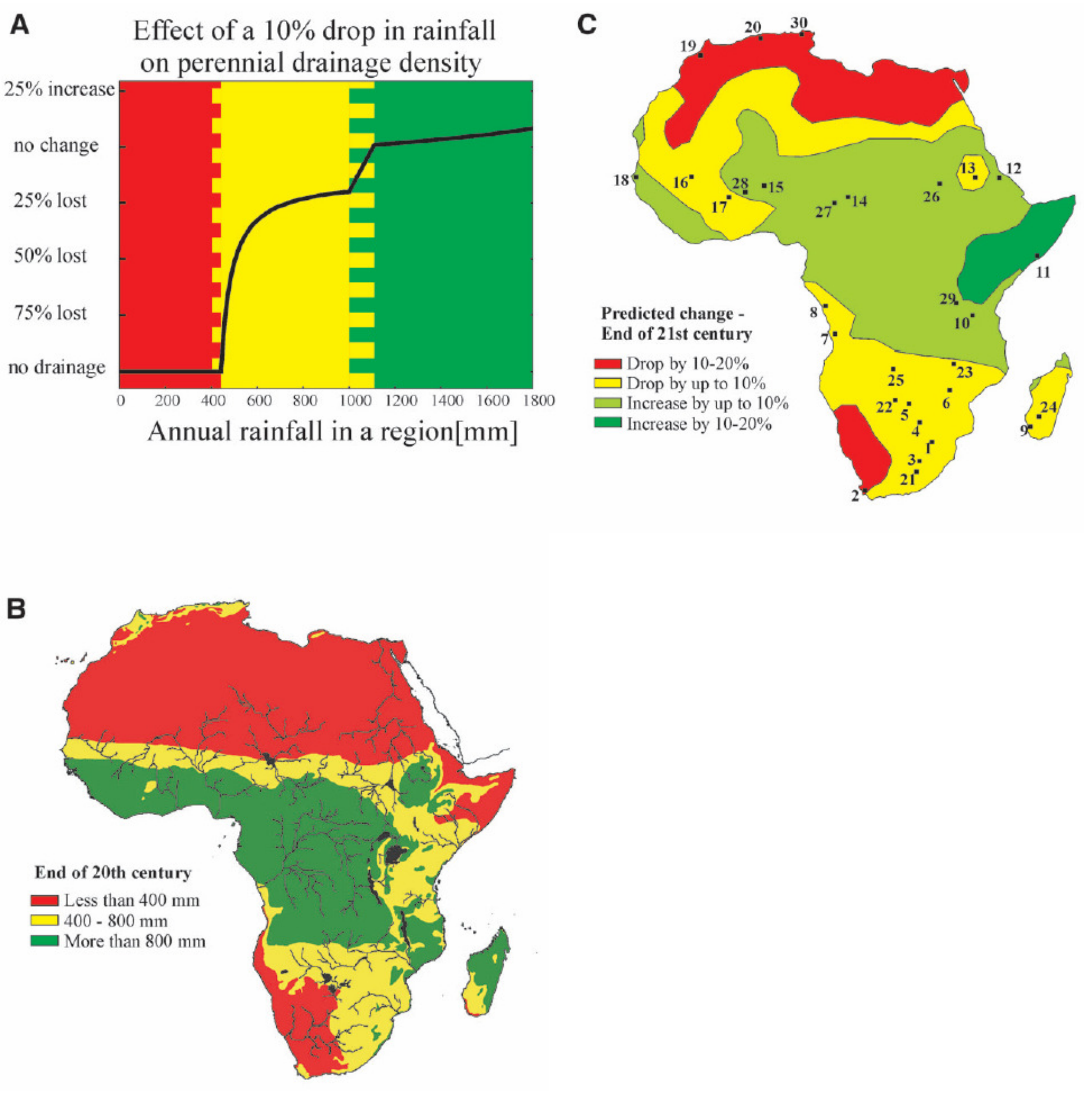
Table 3.6 Percentage of perennial drainage that will remain following a given change in precipitation for the period 2070-2099, Southern Africa.

Stat. #	City	Country	Rainfall	Period	10% drop	20% drop	10% rise	20% rise
1	**Johannesburg**	**SA**	**723**	**1951-1990**	**78**	55	122	145
2	Cape Town	SA	612	1837-1989	71	**42**	129	158
3	**Bloemfontein**	**SA**	**557**	**1903-1990**	**65**	29	135	171
4	Gaborone	Botswana	526	1922-1988	**58**	17	142	183
5	Maun	Botswana	465	1921-1988	**28**	0	172	243
6	Harare	Zimbabwe	830	1890-1989	**81**	61	119	139
7	Catete-Sede	Angola	606	1918-1972	**71**	41	129	159
8	Cabinda	Angola	798	1913-1980	**80**	60	120	140
21	Zastron	SA	570	1979-2000	**66**	33	134	167
22	Okavango	Botswana	460	1973-2003	**23**	0	177	253
23	Chipate	E. Zambia	840	1979-2000	**81**	62	119	136
25		**W. Zambia**	**730**	**1979-2000**	**78**	56	122	144

Source: adapted from (De Wit and Stankiewicz 2006). Likely scenarios are bolded and shaded. See also Figure 3.3 ***(C).***

Based on rainfall projections according to the B1 SRES scenario, (De Wit and Stankiewicz 2006) presume that most of southern Africa will receive 10% to 20% less rainfall by 2050. The authors predict that such reductions in areas with a rainfall regime of 400 - 1000 mm may lead to a drop in perennial surface drainage of 75 to 25 percent respectively by the year 2050. Areas with annual rainfall of 500 – 600 mm, may lose 60 to 30 percent respectively of perennial drainage (see the yellow zones in Figure 3.3 a and c). Although the data mask monthly variation in river flow, such changes in rainfall would have major effects on runoff and perennial drainage in northern Namibia, as all are directly or indirectly dependent on rainfall over Angola and Zambia. Given that the catchments in these two countries on average receive more than 700 mm of rainfall, the projected reductions in rainfall could be expected to lead to a reduction of 20-30% in runoff and drainage of perennial rivers in northern Namibia. Similarly, runoff and drainage in ephemeral rivers in the interior of Namibia may be affected. The results of rainfall-runoff modelling for the Fish River Basin are however presented in the next section.

Figure 3.3 Effect of 10% reduction in rainfall on perennial drainage density by 2070 - 2099 for the B1-scenario (A); Rainfal regimes at the end of the 20th century (B); Map of Africa showing predicted change in precipitation (C). The numbers indicate selected locations for which the effect on perennial drainage density has been calculated.



Source: (De Wit and Stankiewicz 2006)

3.4.3 Impact of climate change on runoff in ephemeral rivers in southern Namibia

Ephemeral rivers flow mainly as a direct response to surface runoff. There is little to no delayed surface or subsurface runoff and definitely no baseflow. This is related to the erratic rainfall pattern, high river bed losses and physical features of most river basins in the interior, characterised by impermeable surfaces with little or no top soils, scarce vegetation and hilly or mountainous terrain (Van Langenhove et al. 1998). For most of the year ephemeral rivers are dry, flowing only briefly with characteristic 'flash floods' when enough rain has fallen over their catchments. Seasonal runoff from ephemeral rivers is stored in large reservoirs near Windhoek and other areas of high water demand (Tarr 1999). The amount of ephemeral water available for use each year depends on the amount of rainfall. Thus it is important to understand the impacts of climate change on runoff in Namibia's ephemeral basins. Since runoff and the flow of ephemeral rivers in arid environments such as in the South of Namibia are subject to specific conditions, rainfall-runoff modelling for catchments of the Hardap and Naute dams in the Fish River Basin was undertaken in collaboration with the Department of Water Affairs. Attempts have further been made to assess impacts on safe dam yields.

3.4.3.1 Methodology

To assess the impact of changes in rainfall on runoff in Namibia, the Namibian Rainfall/Runoff Model (NAMROM) was applied as Namibia is a semi-arid to arid county and its runoff is characterized by a negative serial seasonal correlation (De Bruine et al. 1993). This means that the model purposefully takes rainfall in previous seasons into account, because good rainfall in the earlier seasons increases vegetation cover to such an extent that the runoff potential is actually reduced. The opposite also applies. As this feature is not integrated in most commonly used rainfall/runoff models, NAMROM was developed and gradually modified during the 1990s by (McKenzie and Grobler 1992), (Mostert et al. 1993) and DWA (Republic of Namibia 1998).

The NAMROM model has been applied to six downscaled rainfall scenarios for a future period comprising 20 or 30 years between 2070 and 2100. CSAG provided the downscaled daily rainfall data for the six GCMs for the locations of Mariental and Keetmanshoop. The complete analysis of the rainfall-runoff modelling is presented in Annex 1, whilst the next section presents a summary of the main findings.

3.4.3.2 Future rainfall, runoff and dam yields in the Fish River Basin

The majority of downscaled GCMs indicate that annual rainfall in the period 2080-2100 will increase in both the Hardap and Naute catchments. The models do however not completely agree on the direction of change when it comes to runoff (Table 3.7).

Table 3.7 Direction of change for future rainfall, run-off and safe dam yield, Hardap and Naute catchments (number of models out of 6)

Direction of change (ratio of future / current situation)	Rainfall	Runoff	95% safe dam yield
Hardap catchment			
Decrease (< 0.85)	1	1	3
Constant (0.85 – 1.15)	0	2	0
Moderate increase (1.15 – 1.5)	2	1	0
Substantial increase (> 1.5)	3	2	3
Naute catchment			
Decrease (< 0.85)	1	1	1
Constant (0.85 – 1.15)	0	1	0
Moderate increase (1.15 – 1.5)	4	2	0
Substantial increase (> 1.5)	1	2	5

As far as the Hardap catchment is concerned, half of the models support a decrease in runoff or runoff that remains of the same magnitude, whilst the other 3 models project increases in runoff. In the Naute catchment 4 out of 6 models support moderate to substantial increases in runoff.

In both catchments there are some signs of reduced variability in runoff (4 out of 6 models). This could partially be related to the negative seasonal correlation of rainfall and runoff, caused by improvements in vegetative cover in successive years of more than average rains. Another explanation can be found in the fact that some models predict more regular rainfall patterns, even when they project reductions in total annual rainfall.

In terms of the 95% safe dam yield for the Hardap catchment, the models do not agree on the signal. Whereas some models underlined that runoff would increase or remain constant, they suggest that the safe dam yield will decrease. This is most likely related to a combination of increased evaporation in the future situation and the relatively large surface area of the Hardap dam. In the Naute catchment however, in line with the rainfall and runoff projections, the majority of models substantiates an increase in safe dam yield. On the one hand this may be due to the particular dam characteristics, which support the suggestion that future levels of evaporation will not affect the safe yield of the Naute dam to the same degree as the Hardap dam. It further seems to be due to the fact that the signal of increasing rainfall and runoff in the Naute catchment is consistently stronger than in the Hardap catchment.

In summary, the above suggests that in the Naute catchment the majority of models support an increase in rainfall, runoff as well as safe dam yield. For the Hardap catchment the signals are not so clear. Taking biases of certain models into consideration, the remaining four models are not clear about the signal for runoff, although they support an increase in rainfall in the future. The models that are not characterized by overly dry conditions at the onset of the modelling period further tend towards a reduction of the safe dam yield for the Hardap dam.

3.5 Vulnerability of Namibia's wetlands and water resources to climate change

3.5.1 General impacts on wetlands and water resources based on observed and predicted climate change in Namibia

Currently, of the water that falls as rainfall in Namibia, 83% evaporates, 1% recharges groundwater, 14% returns to the atmosphere through evapo-transpiration, with only 2% remaining for surface water storage (Eales et al. 1996) (Heyns et al. 1998). Rainfall often evaporates before it reaches the ground.

Effects of a general increase in temperature

The predictions for Namibia are that temperatures will increase throughout the country, both in summer and winter, more so in the east than along the coast. Maximum summer temperatures in the east could go up by as much as 3°C or more. This will have a marked increase on evaporation, as it is estimated that for every degree of temperature, evaporation increases by 5%. Increased evaporation and resultant evapo-transpiration losses will leave even less water available for recharge and storage. Increased evaporation will decrease the length of inundation of seasonally flooded wetlands, and may lead to increased salt content of pans and pools. Increased temperatures will also lead to an increase in transpiration from plants, which will mean that they are pumping out more groundwater or using more surface water e.g. from pans. All this will result in a reduction of the size and productivity of many wetlands.

Table 3.8 Overview of climate change vulnerabilities for Namibia’s water resources: temperature, evaporation, rainfall and perennial drainage

Climatic Issue	Model agreement	Direction of change	Primary impact	Secondary Impacts
Temperature increase	Yes	• Warming: (increases of between 1°C and 3,5°C in summer and 1°C to 4°C in winter) • Hottest days become more frequent (observations across weather stations in Namibia)	Increased evaporation and evapotranspiration (increase of 5% - 15%)	Flood plains, oshana’s and pans dry out sooner. Shorter life cycles for fauna and flora, causing reduced productivity of wetlands
				Increase in salt content of pans and pools
				Increased water usage by people, animals and plants
				Higher crop water demands reduces dryland cropping potential
				Less water available for runoff
				Lower water table in ephemeral rivers with negative impacts on water levels in springs, wells and waterholes. Affects riparian vegetation, animals and people.
Rainfall / perennial drainage	Models do not always agree: • Information from GCMs for Southern Africa not always in line with downscaled modelling for Namibia • Rainfall modelling for Namibia is merely conclusive for central and north-eastern regions	Observed historic trends depict: • Increase in the duration of the dry season • Shortening of the rainy season and • Decrease in the number of consecutive wet days Projections for the future vary; • Global models predominantly suggest drying in Namibia as over Southern Africa (10-20% less rainfall); Downscaled models predict: • An increase in late summer rainfall over central and north-eastern regions for the mid-century, and; • Drying trend in the Southwest	<u>For the North:</u> Reduction in runoff and drainage of perennial rivers by +/- 25% (2045-2065)	<u>General impacts:</u> • Smaller area of flood plains inundated, drying out sooner; • Disruption of seasonal breeding cycles of invertebrates, fish and flora; • Reduced productivity of flood plains and floodplain lakes

Already some rainfall evaporates before it even reaches the ground and some evaporates almost directly on striking the often warm earth or rocks. With increasing temperature this will be exacerbated and could lead to less water being available as runoff. Decreased runoff will lead to a lowering of groundwater tables. This in turn will lead to a die off of riverine vegetation, which will affect the people and animals dependent on the vegetation. Direct use of groundwater by people and animals will also be adversely affected. Ephemeral rivers are dependent on sporadic flooding not only for groundwater recharge, but for recruitment of young trees before their roots reach the groundwater.

Effects of changes in rainfall patterns

Changes in rainfall patterns are not so clear and vary for different regions of Namibia. The general prediction is that rainfall will decrease by 10-20% in southern Africa (De Wit and Stankiewicz 2006). If this includes Namibia, it will seriously affect all inland wetlands, as all are directly or indirectly dependent on rainfall in Namibia. The predicted decrease in rainfall will lead to decreased runoff, which affects the groundwater aquifers and seeps, all the vital linear oases, many of the springs and our floodplains and pans. Pans will not last for as long, or may not fill at all as drought conditions will probably also increase.

Given the spatial variation in predictions for future rainfall in Namibia, the specific impacts of changes in rainfall patterns on different areas in Namibia are discussed in the following sections, which make a distinction between northern Namibia and Namibia's southern, interior and coastal zones.

3.5.2 Vulnerability of wetlands and water resources in Northern Namibia

As far as the vulnerability of wetlands in northern Namibia is concerned, future patterns of rainfall over western Zambia and Angola are relevant. (De Wit and Stankiewicz 2006) seem to expect a reduction of 20 to 30 percent in annual perennial drainage over this area (Table 3.6). Generally, this would seriously reduce the area of floodplains inundated each year in northern Namibia. Smaller and shallower floodplains would dry out more quickly and this could disrupt the seasonal breeding of many invertebrates and fish.

Although the amount and intensity of rainfall over western Zambia and Angola are major factors that influence the flow of the Zambezi waters into the floodplains in the Caprivi, the rivers of the north-east are less likely to be adversely affected strongly because of the volume of water which comes down in these rivers, and the current lack of impoundments. Yet the productivity of the floodplains and floodplain lakes alongside these rivers would be adversely affected. This will be discussed in more detail in section 3.5.3.2.

The rivers most likely to be affected by the predicted decrease in flow from Angola are the Kunene and the Cuvelai system. A decrease of 20-30% in the Kunene, if coupled with increased extraction of water to meet the increased water demands of central northern Namibia, could have a serious effect on this river system, especially at the mouth. If Matala and Gove Dams in Angola are restored, or any other dams built, including the proposed dam for hydroelectricity in the vicinity of the Baynes Mountains, it could have serious consequences for the river and its associated fauna, flora and the people that are dependent on it.

The trends depicted in Figure 5 in chapter 1 moreover show that rains in the central north are likely to start later and end earlier, with an overall decrease in the duration of the rainfall season. The Cuvelai wetlands of this area are recharged partly by rainfall in the area, and partly by runoff from rainfall in Angola. Thus with both rainfall and runoff decreasing, there could be a serious impact on this very important system. This would be exacerbated by increases in summer temperatures, with increased evaporation decreasing the length of inundation of the oshanas and potentially increasing the salt content of pools in the system. The oshana system is already under stress due to high usage, with infrastructure obstructing the natural flow of the water and reducing groundwater recharge (Eales *et al* 1996). Livelihoods could thus be affected directly by reducing water availability, fish and frog stocks, as well as edible plants. Decreased water in the system could also reduce the availability of raw materials for building and craft. Reduction in recharge of the subsurface aquifers would lead to the death of trees which are important for wood, shade and fruits.

Etosha Pan could also be seriously affected, since it is dependent on really big flood events or *efundja* to fill with water from the Cuvelai system. Decreases in rainfall and runoff and increases in evaporation will have a marked effect on the pan and its associated wildlife, particularly the flamingos that breed there, who rely on just the right amount of inundation to keep predators away but not flood their nests in what is a very shallow pan. The effect of climate change could be compounded by increased abstraction of groundwater from surrounding aquifers, e.g. the Oshivelo Aquifer, for seeps and waterholes. The combined effect of predicted climate change and increased abstraction would in turn have a large impact on tourism to the area.

3.5.3 Vulnerability of wetlands and water resources in the Caprivi

There are basically three types of wetlands in the Caprivi; the perennial rivers that are fed from rainwater to the north of Namibia, the seasonal floodplains and lakes that are inundated by water from these rivers, and the ephemeral rainwater pools. For the purposes of this chapter, we are regarding the Okavango River as being part of the Caprivi wetland system.

In perennial systems, water provides a three dimensional habitat. An increase or decrease in the volume of water can have a large effect. A decrease in water flowing through the system will decrease the variety of habitats and lead to a loss of biodiversity.

3.5.3.1 Perennial rivers in the Caprivi

The Kwando and Zambezi Rivers bring water from Angola and Zambia, and are interconnected by a complex system involving the Linyanti and Chobe Rivers, as well as Lake Liambezi. The Okavango and its major tributary, the Cuito, drain the Angolan highlands. De Wit and Stankiewicz (2006) predict that rainfall in southern Africa will most likely decrease by 10%, leading to a reduction in surface drainage to around 71-80% of current drainage (Table 3.10). This is unlikely to affect the fauna and flora of the rivers themselves, except in exceptionally dry years.

High water temperatures and longer periods of low flow tend to exacerbate many forms of water pollution (IPCC 2007). Pollutants include sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt. When runoff declines we could find a reduction in the services provided by the water resources, thus climate change could affect not only the quantity of water, but also the quality.

Table 3.9 Overview of climate change vulnerabilities for water resources: impacts of changes in rainfall, runoff and drainage in Namibia’s northern regions

Climatic Issue	Model agreement	Direction of change	Primary impact	Secondary Impacts
Rainfall / perennial drainage	Models do not always agree: • Information from GCMs for Southern Africa not always in line with downscaled modelling for Namibia • Rainfall modelling for Namibia is merely conclusive for central and north-eastern regions	Observed historic trends depict: • Increase in the duration of the dry season • Shortening of the rainy season and • Decrease in the number of consecutive wet days Projections for the future vary; • Global models predominantly suggest drying in Namibia as over Southern Africa (10-20% less rainfall); Downscaled models predict: • An increase in late summer rainfall over central and north-eastern regions for the mid-century, and; • A drying trend in the Southwest of the country	25% reduction in drainage	**Kunene:** • Reduced flow, increased salinity and closing of the mouth, with negative influence on fauna and flora and the potential as a Ramsar site • Added stressor: increasing human demand for water for Angola and the interbasin supply in the central north
			25% reduction in drainage	**Cuvelai:** • Reduction of productivity of oshana’s, affecting livelihoods • Reduction of flood related damages • Increased salinity of water
			25% reduction in drainage	**Etosha:** • Less frequent efundja recharge of Etosha pan
			25% reduction in drainage	**Caprivi:** • Reduction of water retention in marshes • Duration of river flow and extent of flooding may be reduced • Lake Liambezi likely to be dry for longer periods • Reduced productivity of flood plain, affecting rural livelihoods • Low flow of Zambezi could affect flooding in Chobe, with negative impacts on tourism • Ecosystem services (water purification, flood attenuation) seriously affected • Negative impact on lifecycle of killifish in rainwater pools
			25% reduction in drainage	**Okavango Delta:** • Potential shift to a seasonal river

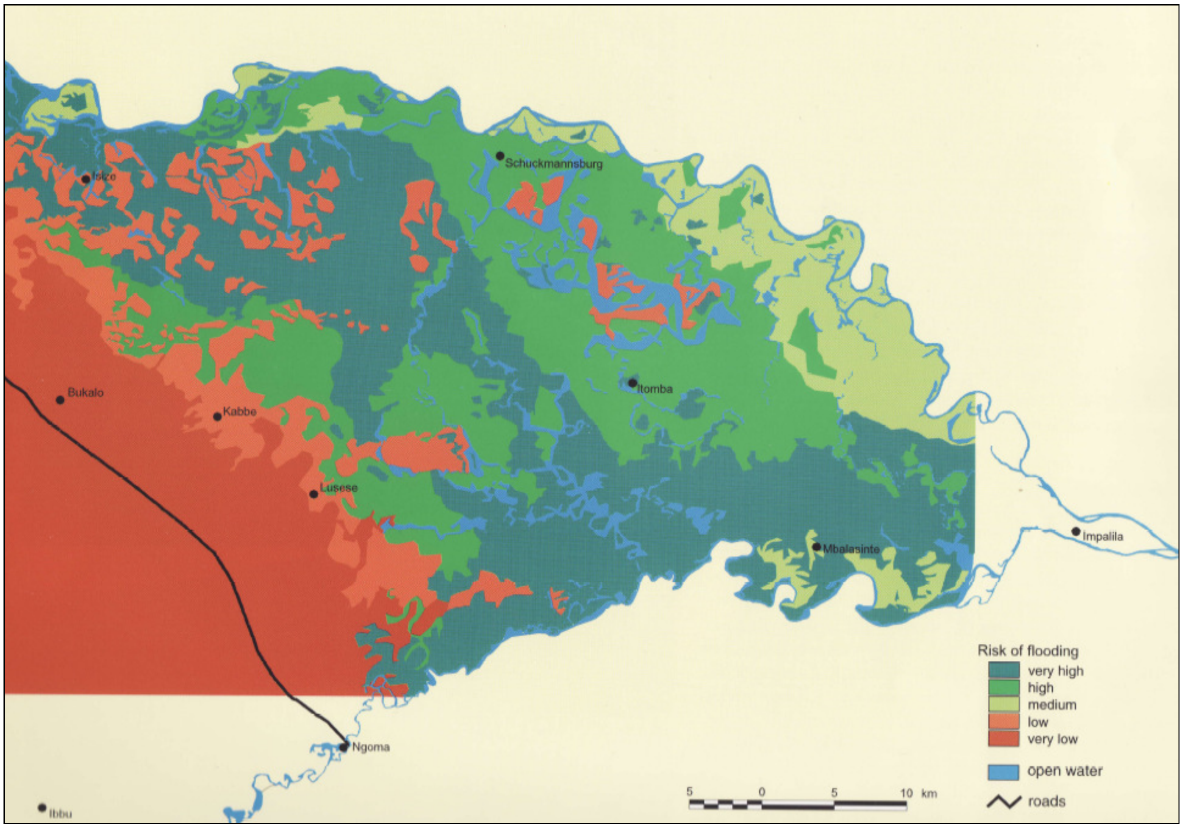
3.5.3.2 Seasonal floodplains and ephemeral lakes in the Caprivi

When the perennial rivers flood, water flows into the floodplains on either side of the river. At the height of the flood the floodplains may be extensive, reducing to small pools or disappearing at the lowest ebb of the flood. A reduction in flow of the rivers could have a marked effect on these important floodplains. The area of the floodplains will reduce, as well as the duration of inundation, which will lead to a decrease in productivity. Lake Liambezi is a highly productive ephemeral lake connecting the Chobe and Linyanti Rivers. In wet years it fills with water, providing a habitat for a large variety of animals and fishing for the people living around it. In consecutively dry years it dries up completely. With reduced flooding of the Kwando and Zambezi Rivers it will be dry for longer periods.

The seasonal flooding is essential to the productivity of these systems. Runoff from rains in the catchment in January/February reaches Namibia in March/April. This delayed flooding allows the floodplain pools to fill with rainwater in the Namibian rainy season.

Increased temperatures will affect the temperature of these seasonal habitats, reducing the habitable size. It will also affect the rate of evaporation, thereby decreasing the duration of inundation even further. This may be counteracted by the increase in late summer rainfall predicted in chapter x, which could provide a boost to pools which are starting to dry up.

Figure 3.4 The risk of flooding on the eastern floodplains in the Caprivi



Source: (Mendelsohn and Roberts 1997)

Box 3.1 The risk of flooding on the eastern floodplains in the Caprivi

(Mendelsohn and Roberts 1997) provide an overview of areas in the Caprivi flood plains that are likely to be flooded (see also Figure 3.4). The areas that are rated "very high" are likely to be flooded most frequently and extensively. Those rated "low" are likely to be flooded only rarely, perhaps only once in 50 years.

Until Independence the local population was fairly well adapted to intermittent flooding of the flood plains, as households moved to higher elevations in the Caprivi in years of high floods. Since Independence infrastructure and settlements have been developed in the floodplains and people were encouraged to settle more permanently and to farm on the known flood plains, as a result of which such traditional ways of adaptation to floods have diminished (Mendelsohn and Roberts 1997).

A number of these settlements are very likely to be threatened by high flood waters, especially when levels of the Zambezi were to reach heights similar to those recorded on 1989. According to 1997 estimates high flood waters may affect approximately 3600 households or 20,000 individuals (Mendelsohn and Roberts 1997). During the 2004 flood, when water levels reached 6.65 meter in April, approximately 20,000 people were affected, of which 5,000 needed relocation to higher grounds at centres such as Lusese/Kabbe, Impalila and Schukmansburg (Republic of Namibia 2004c). Lives are most of the time not at stake during the floods, but food supplies and livestock are threatened. Usually a number of schools in the flood plain have to be closed.

3.5.3.3 Rainwater pools in the Caprivi

Although the majority of the wetlands in the Caprivi are supported by runoff from further north, there are numerous rain-fed pools scattered around eastern Caprivi. These form important habitats for frogs and invertebrates, as well as endemic fish, the Caprivi killifish, *Nothobranchius* spp which breed in these seasonal pools. A decrease in rainfall could have an effect on the pools, both in terms of size and duration of inundation. Increased temperature would also affect them, in terms of increasing the water temperature, decreasing duration of inundation due to evaporation and increasing salt content of the pools by evaporation. Again, the increase in late summer rains may counteract these effects.

3.5.3.4 Impacts of ecosystem goods and services and livelihood impacts

Decreased flow in the river could mean that at times of low flow there would be less water available for use by the people living along the banks, and possibly reduced water available for riparian vegetation during low flow. It should not have a significant effect during flooding. Decreasing the size of the floodplain pools, and length of inundation, would affect the length of time that food resources such as fish and aquatic plants are available. A decrease in the flooded area could affect the source of raw materials such as reed beds and thatching grass, as well as a decrease in grazing area. A reduction in low water levels could have an effect upon services such as aquifer recharge, improvement of water quality and shade provision.

Products such as water, fish, freshwater mussels, aquatic and other plants dependent on the river are used for food and medicine, trees for timber, shade and fuel, reeds, sedges and grasses for hut construction and craft. Services such as water purification, flood attenuation and nutrient recycling could be seriously affected.

3.5.3.5 International shared river impacts

The greatest impact would be on the Okavango River downstream of Namibia, namely the panhandle and delta in Botswana. Decreased run-off from the Angolan highlands, together with increased evaporation could lead to a far greater decrease in river flow in Botswana than is experienced in the Namibia section of the river. Less flow could also reduce the capacity of the river to transfer sediments as base flow. A decrease in the sandy sediments transported to the delta will affect the ecological functioning of the system (Nampower 2004 in Beekman *et al* 2006). This could have disastrous consequences for the ecology of the delta, and an impact on the lucrative tourism supported by the Delta. What about recession farming?

Only a small section of the Zambezi flows through Namibia, and this is unlikely to be significantly affected by activities in Namibia and will thus not have an impact on neighbouring Zambia, or Zimbabwe and Mozambique downstream. However, a reduction in the flow of the Zambezi could affect flooding in the Chobe, which could affect tourism in Botswana. Game, particularly elephants and lions from the Botswana side could cross the river more easily and become a problem for rural farmers in Namibia. The main impact would be reduced inflows into the floodplain lakes such as Lake Liambezi and Lisikeli lake.

3.5.4 Vulnerability of wetlands and water resources in the South, the interior and the coastal zone

The vulnerability of wetlands in the interior and the South is not only determined by changes in total annual rainfall and summer rainfall, but by changes in winter rainfall as well. Figure 6 in chapter 1 predicted that winter rainfall will decrease in the so-called winter rainfall area of the south-west. This is expected to have a detrimental effect on the terrestrial ecosystems, but will not affect the only large wetland there, namely the Orange River Mouth, since this is fed from runoff from further east. There are however many much smaller ephemeral desert pools that rely entirely on what little rain there is, to come alive intermittently. The very special desert adapted aquatic invertebrates supported by these pools are little studied and may well prove important in terms of biodiversity. In the mid 80s a new genus of Anastaca or fairy shrimp was found (Roberts, K. personal communication). These ephemeral pools and seeps are also important to the wildlife such as gemsbok and brown hyaena of the southern Namib. Any reduction in the already very low rainfall of often less than 20mm will have serious consequences to the animals dependent on the little freshwater available.

The Orange River itself would however be affected by the reduction in rainfall over the eastern part of South Africa, with likely dire implications for river flow in the lower reaches of the Orange along Namibia's southern border (De Wit and Stankiewicz 2006).

Summer rainfall is predicted to increase over the coast, but it is uncertain as to what will happen in the rest of the country. In the central north of the country it is predicted that the onset of rainfall will be later, with cessation earlier, resulting in an overall decrease in the duration of the rainy season. In late summer rainfall over most of the country could increase. This, combined with an increase in winter rainfall, may offset the general decrease in duration of rainfall. Although it must be remembered that the winter rainfall area is very small compared to the summer rainfall area and the winter rainfall is very low compared to summer rainfall. The south-west or winter rainfall area typically receives less than 100 mm of rain a year and for the most part less than 20mm.

Both increased late summer rainfall and increased winter rainfall could help to extend the life of ephemeral pools and pans, and counteract the drying effect of increased temperature and evaporation. Whether it would have any effect on runoff would depend on the nature of that rainfall. An increase in early summer rainfall predicted for central Namibia and the south, excluding the south-west, could result in pans filling earlier and lifecycles being completed earlier.

The ephemeral rivers not only need floodwater for recharge of aquifers and providing water for new growth on a regular basis, but periodic big floods serve to clear out excess growth and debris that has accumulated in the river bed and thus to transfer nutrients downstream. Floods in ephemeral rivers such as the Kuiseb are also important to keep the dune sea from encroaching northwards.

Climate change could affect wetlands indirectly, by exacerbating other factors that are impacting wetlands. For example, in the Kuiseb and Omaruru catchments, bad farming practices and droughts have lead to a reduction in vegetation cover (Eales *et al* 1996). This has lead to siltation of the rivers with clays from the topsoil, which serves to seal the river bottom and so prevents groundwater recharge. A decrease in rainfall, combined with higher temperatures, could lead to further vegetation loss and siltation of rivers. Conversely, an increase in vegetation due to bush encroachment may lead to decreases in runoff and increased transpiration. It has been suggested that atmospheric CO_2 has a positive effect on water use efficiency by decreasing transpiration (Rohde and Hoffman 2007), which could counteract the increase in transpiration due to increased temperatures.

3.5.4.1 Implications for the vulnerability of wetlands in Karas

Rainfall projections made in chapter 1 concerned a 20-year period around 2055; they predict increased rainfall in the late summer, which concerns both total rainfall and the number of days. Predictions for the winter period are however ambivalent and only support drying in the South-West (figure 6, chapter 1). The result of downscaled GCM simulations for rainfall/runoff modelling in the Fish River Basin (see section 3.4.3 and Annex A) predict moderate to substantial increases in rainfall for areas around Mariental and Keetmanshoop towards the end of the 21st century, but not support increases in runoff across the board; projected changes in rainfall have different effects on runoff for the Hardap and Naute catchments. Overall it appears that predictions are for a moderate increase in runoff for Naute dam and a decrease or 'constant' runoff for Hardap.

Naute dam is used as a tourist resort, to supply water to Keetmanshoop and for the irrigation of crops, particularly dates, but the dam itself is not used by wildlife to any extent. An increase in runoff could lead to a greater release of water from the dam, which would not have any negative impact on downstream wetlands, in fact the impact would be positive. The decrease in runoff to Hardap is more likely to have an impact downstream, as less water is likely to be released from the dam. This could affect the downstream users such as farmers and tourist lodges and may mean that the Fish River Canyon will need to be closed to hikers for a longer period each year when water is not readily available in its pools.

Table 3.10 Overview of climate vulnerability for water resources: impacts of changes in rainfall, runoff and drainage in Namibia's southern regions

Climatic Issue	Model agreement	Direction of change	Primary impact	Secondary Impacts
Rainfall / Runoff	Rainfall-Runoff models for southern Namibia do not agree on direction or magnitude of change	**For the South:** • Majority of downscaled models predict an increase in total rainfall for 2080-2100 (modelled data only available for the South of Namibia)	**For the South:** Hardap catchment: • only half of the models substantiate increased runoff Naute catchment: • increased runoff according to 2/3 of models	Dam yield • Mixed signals for impact on 95% safe dam yield for Hardap • Increase in safe dam yield for Naute for majority of models
		• 10% reduction in rainfall over highlands in SA that feed the Orange river	• 25% reduction in flow of Orange river	• Mouth of Orange river may close; negative consequences for the Ramsar site

Increased temperatures are predicted here too, with an increase in the number of days with temperatures over 35˚C. This will seriously affect the lifespan of ephemeral pans, as well as the rate of evaporation from dams. It will also increase transpiration of riparian vegetation, which will have an effect on the groundwater.

The Orange River Basin is one of the driest in southern Africa (Beekman *et a*l 2006), with over 50% classified as hyper-arid to semi-arid. The river as a whole has been allocated a water stress indicator value of 0.8-0.9, where 0 = no stress and 1 = high stress, due to over-abstraction of water (Eales *et al* 1996). A decrease in rainfall upstream as predicted by (De Wit and Stankiewicz 2006) could affect the amount of water released from the numerous impoundments upstream, with serious effects downstream, especially at the already stressed RAMSAR site at the mouth.

3.6 Impact of climate change on groundwater recharge

As stated earlier in this chapter the arid and variable climatic conditions in Namibia are underlined by high levels of evaporation and high average water deficits. A major share of the limited amount of rainfall that falls evaporates or is drained rather quickly by ephemeral rivers. This means that a major part of precipitation in Namibia does not appear as surface water, as only 2% of annual rainfall creates surface runoff. Moreover, only 1% of annual rainfall infiltrates into the ground according to Namibia's general water balance and only 30% of this infiltrated water is expected to recharge aquifers (Eales et al. 1996; (Heyns et al. 1998). Beekman & Xu (2003) in Beekman *et al* (2006) give a range of groundwater recharge of 1 – 15% of average annual rainfall for southern Africa. The only area where it may be higher than 1-2% in Namibia is in the limestone rocks of the Karst area around Tsumeb, Grootfontein and Otavi.

Although only a very small proportion of rainfall reaches the saturated zone underground, the process of groundwater recharge has been going on for thousands of years, resulting in substantial reserves of groundwater. In a country where surface water is sparse and merely found along the borders, groundwater is therefore an important resource, especially in the interior of the country. Estimates suggest that 45% to more than half of all water used by people in Namibia is abstracted from aquifers, whilst 78% of the water used by livestock is also abstracted from groundwater sources. The major rivers along the borders of Namibia, which have the capacity to hold surface water, at the same time support about 33% of the population; (Christelis and Struckmeier 2001; Mendelsohn et al. 2002).

Table 3.11 Water supply and demand in Namibia in 2000: the relative importance of groundwater

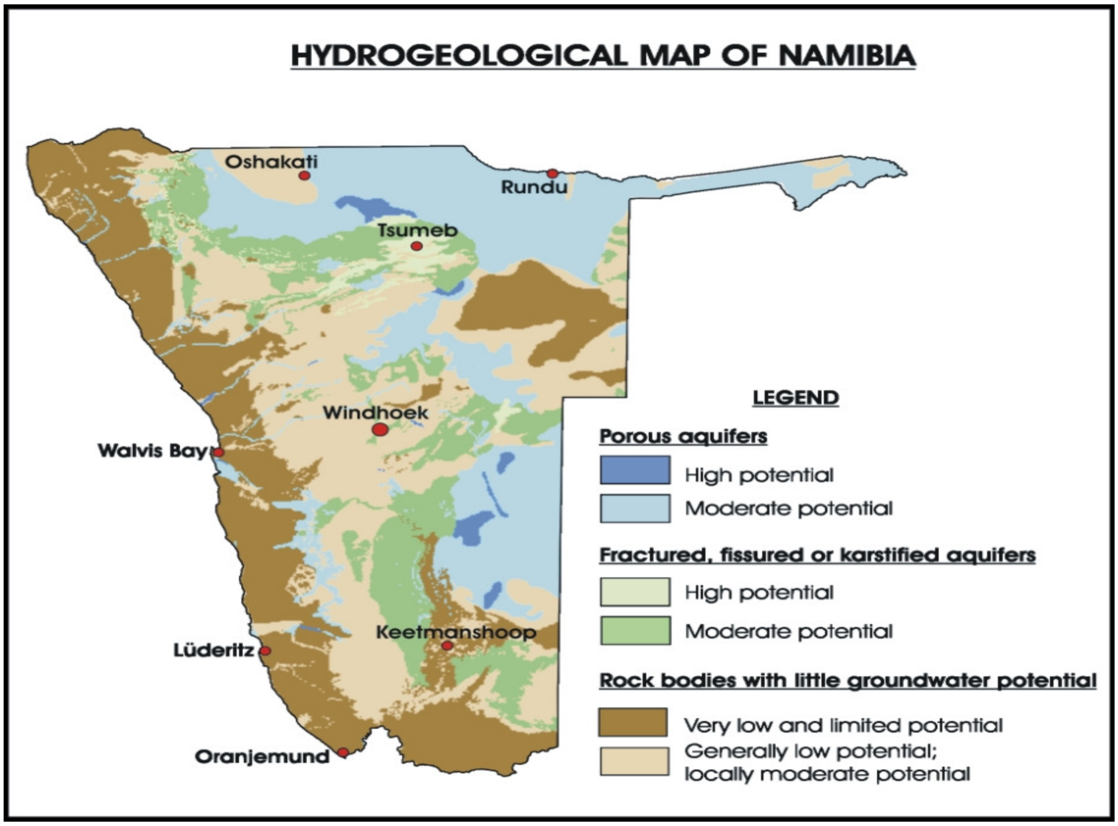
	Consumer Group	**Volume**	**Perennial Rivers**		**Ephemeral Rivers**		**Groundwater**	
Supply		Mm3	Mm3	%	Mm3	%	Mm3	%
	Total	**660**	**150**	**23 %**	**200**	**30 %**	**300**	**45 %**
Demand	Domestic	73	18	25 %	20	27 %	35	48 %
	Stock	77	14	18 %	3	4 %	60	78 %
	Mining	14	8	57 %	1	7 %	5	36 %
	Irrigation	136	60	44 %	41	30 %	35	26 %
	Total	**300**	**100**	**33 %**	**65**	**22 %**	**135**	**45 %**

Source: After (Christelis and Struckmeier 2001)

Namibia's groundwater occurs in a wide range of soil types making groundwater management a complex task, all the more since the knowledge of flow systems and the impacts of human activity is very partial. Groundwater in Namibia continues to provide a buffer against drought in many regions of the country, but given the limited knowledge and the variable climatic and hydrological conditions, it is also highly vulnerable to over-exploitation (Republic of Namibia 2000). Under these conditions, the development of groundwater resources for human consumption depends on best estimates of the sustainable yield of aquifers. To prevent large-scale mining of groundwater resources, careful monitoring of rainfall, runoff, groundwater recharge and groundwater extraction is essential (Jacobson et al. 1995). Ultimately all groundwater comes from rainfall and runoff via recharge and as such it is relevant to get an understanding of how climate variability and climate change affect groundwater recharge (see section 3.6.4).

The next sections discuss groundwater recharge in the Fish River Basin, the Caprivi and western ephemeral rivers, before addressing the impact of climate change on groundwater resources.

Figure 3.5 Hydrogeological map of Namibia



Source: (Christelis and Struckmeier 2001)

3.6.1 Groundwater recharge in the Fish River Basin and Stampriet Artesian Basin

Major parts of the Hardap and Karas regions, to the east of the Namib desert, between Mariental in the north and Ariamsvlei in the south, belong to the large hydro-geological unit of the Fish River Basin and the Keetmanshoop – Aroab area. The largest town in the area, Keetmanshoop, receives surface water from the Naute dam. Smaller towns like Aroab, Maltahohe, Kalkrand, Gibeon, Berseba and Bethanien rely on groundwater from aquifers in the Nama sediments. The landscape is extremely barren and rocky with little soil cover. The vegetation consist of dwarf shrubs with some trees in river beds (Christelis and Struckmeier 2001).

Groundwater levels in this area are generally shallow in the east, close to the course of the Fish River, but become progressively deeper towards the escarpment in the west, where water levels deeper than 200m are recorded. Groundwater in the area is found in two main types of aquifers; in primary alluvial aquifers and in secondary aquifers in fractured sedimentary bedrock. The alluvial aquifers are found in sediments beneath some ephemeral rivers, including the Fish River, and are relatively shallow. The quality of Fish River groundwater varies temporally and spatially and is often not potable (Boonzaaier et al. 2000).

Most of the smaller towns rely on secondary aquifers in the fractured sedimentary bedrock of the Nama Group for the supply of water. Groundwater is found in faults and joints in the sedimentary rocks of this geological formation. These aquifers are deeper than the alluvial aquifers and recharge is usually from exceptional or historic events, including those of previous, wetter geological periods. Aquifers that are not recharged by present day rainfall are often termed 'fossil water'. Generally, the bedrock in this area does not have a high water-bearing potential. Hence, the aquifers vary in size, occurrence, yield and quality of water and usually only provide sufficient water for farms and smaller settlements. Detailed geological fieldwork is often required to find the suitable location for drilling of boreholes that can access potable water and provide adequate yields (Boonzaaier et al. 2000; Christelis and Struckmeier 2001).

Some of the aquifers in or close to the Fish River Basin are artesian, such as the Maltahohe artesian aquifer, which is situated about 30km to the west of Maltahohe. To the east of the Fish River Basin one moreover finds the Stampriet Artesian aquifer. Both these aquifers are designated Groundwater Control Areas, which means that groundwater abstraction from these aquifers is monitored to prevent undue depletion of resources. In practical terms this implies that farmers operating in these areas have to obtain permits to abstract groundwater and they have to monitor and report on water utilisation. (Boonzaaier et al. 2000) however stated that law enforcement used to be limited and that illegal abstraction and irrigation were probably happening, thereby endangering the sustainable use of the aquifer.

Table 3.12 Estimated potential annual groundwater recharge in the semi-arid and sub-humid regions of Namibia

Climatic region	Area (km²)	Mean rainfall (mm)	1% infiltration (Mm³)	30% recharge (m³/km²)
Arid	453,855	50	226.9	150
Semi-arid	304,563	300	913.7	900
Sub-humid	65,851	500	329.3	1500
Total	824,269		1,468.9	

Source: (Heyns et al. 1998)

Groundwater recharge rates in the Fish River Basin are generally slow and erratic, due to the fact that the surface in the region is mostly hard and impermeable. Artesian aquifers generally are not recharged under present conditions. Precipitation is limited and highly variable, but when it rains a major share of rainfall quickly disappears as runoff and this is compounded by a generally limited recharge proportion of less than 1 percent. An estimated potential recharge rate for arid climatic regions in Namibia in general is in the realm of 150 m³/km²/year (Heyns et al. 1998), but many scientists presume that recharge in regions with mean annual rainfall below 400 mm is non- existent. It is therefore likely that the proportion of groundwater recharged by contemporary rainfall is limited and that borehole abstraction in many places is greater than the recharge rate. This means that the groundwater resources in the region are currently vulnerable to over-abstraction. Mining of non-renewable groundwater, including fossil water, is therefore likely to happen.

3.6.2 Groundwater recharge in the Caprivi region

The hydro-geological region of the Caprivi comprises the territory east of the Kavango River. It is a flat area that is characterised by relatively uniform geological conditions at the surface, dense vegetation, the highest level of mean annual precipitation and the lowest evaporation rates in the country. Groundwater is sourced from a porous aquifer in the Kalahari Sequence (Christelis and Struckmeier 2001). These underground water reserves are generally fairly abundant and they are relatively close to the surface and mostly recharged by the surrounding rivers. Recharge in the central part of the hydro-geological region of Caprivi is not informed by rivers but by precipitation. In many parts of the region water can be found between 10 and 40 metres below the surface. Water is closest to the surface in the eastern floodplains and in the southern areas of eastern Caprivi. The deepest water reserves are found in the West of the Caprivi (Mendelsohn and Roberts 1997).

Table 3.13 Main characteristics of groundwater provinces in the Caprivi region

Province	Location	Water level	Quality	Quantity	Remarks
Caprivi West	Interior between Okavango and Kwando rivers	Depth to water deepens towards the west	Good to B	Sufficient	Too deep for hand pumps
Kwando	20 km zone along Kwando River		Generally A, at times B to D quality due to iron content	High yield	
Linyanti	20 km zone north of Linyanti	Deep in the northern part of the Linyanti area	Poor; high concentrations of sulphates and total dissolved solids; lower aquifer = saline; 'black mud'		Hand pumps cannot be used in the part of the area where water is deep
Northern		Deep in the far North of Northern Province	Group A to D; sodium, sulphate and chloride		Too deep for hand pumps in far North
Zambezi – Chobe	Between Zambezi and Chobe Rivers	Shallow	Usually good, but iron concentrations can lead to Group B to D quality		Hand pumps possible

Source: after (Christelis and Struckmeier 2001)

(Christelis and Struckmeier 2001) divide the Caprivi in 5 distinct hydro-geological provinces. The main characteristics are presented in Table 3.13. It underscores that groundwater properties and water quality are highly variable throughout the region. Sulphates, chlorides, high concentrations of dissolved solids and iron are a major matter of concern, as a result of which a high proportion of water points is classified as Group D water. The iron problem can however be overcome with a low-technology iron removal system. Groundwater of good quality is usually found at a distance of 5 to 20 km from rivers, which recharge the aquifers. The further away one moves from the rivers and with increasing depth to groundwater, the water quality tends to deteriorate rapidly. Some underground water is not palatable, especially in the area to the north of the Linyanti Swamps (Mendelsohn and Roberts 1997).

Certain areas in the Caprivi are further characterised by boreholes with low yields and clogging, which is mostly caused by poor borehole design and construction (Christelis and Struckmeier 2001).

An important part of groundwater in the Caprivi is recharged by water that seeps through the river beds of the various rivers that surround and dissect the region. Since these rivers in the Caprivi flow all year round, this means that aquifers in the Caprivi can more or less be recharged on a continuous basis, although it is likely that more recharge will occur during the seasons of high river flow, given the larger volumes of water that pass through the rivers. (Heyns et al. 1998) estimate that, in the sub-humid regions of Namibia, to which the Caprivi belongs, annual recharge of aquifers amounts to 1,500 m^3/km^2, which is 10 times the rate of recharge that occurs in arid regions such as the Fish River Basin or the western interior. Groundwater in the Caprivi region is therefore less likely to be depleted and a far less finite and less vulnerable resource than in the South of the country.

3.6.3 Groundwater recharge in ephemeral rivers in the western interior

Groundwater stored in the alluvial deposits in the catchments of western ephemeral rivers, although of limited significance to large-scale development in agricultural and industrial sectors, is also a critical source of water for the population of towns such as Walvis Bay, Swakopmund, Henties Bay and Arandis. In addition farmers in these western catchments depend on water pumped from boreholes and wells along the banks of the rivers. In this regard the alluvial aquifers of the Omaruru and Kuiseb Rivers are particularly important. Furthermore, alluvial aquifers constitute an important supply of water to riparian forests that characterise the lower reaches of the larger ephemeral rivers (Jacobson et al. 1995). The riparian vegetation represents a key resource in terms of forage production for livestock, and further provides building material and fuelwood for local communities. In the lower-middle Kuiseb e.g. there is little or no vegetation outside the river channel and as a result livestock largely depend on riparian vegetation for their survival (Benito et al. 2007).

Even without considering the possible impacts of climate change, the catchments under consideration are very arid and therefore vulnerable to over-utilisation and exploitation of finite water resources, especially when there is little information about the frequency of recharge of alluvial aquifers (Jacobson et al. 1995).

Recharge of groundwater in the western regions mostly occurs in alluvial aquifers of ephemeral rivers and is merely regulated by flood events. Direct infiltration of rain in arid desert regions is usually non-existent, as high evaporation and hard surfaces and relatively high levels of runoff prevent this. The amount of recharge through ephemeral river beds depends on the intensity, duration and volume of the flood. Thin layers of clay in the river bed may prevent infiltration of water during weaker floods. Intense and turbulent floods however break up the clay layer and allow infiltration in the aquifer to occur. (Lange 2004) provides some evidence that the most significant transmission losses in the Kuiseb catchment concentrate during peak floods, especially when the river floods overbank areas, and are minor during small to medium flows. Therefore, peak floods are important for recharging groundwater under the broader floodplains and for sustaining the riparian vegetation along the banks of ephemeral rivers.

(Dahan et al. 2007) conducted a more detailed experimental study that monitored the infiltration process of floodwaters in the Kuiseb river from the surface of the river bed, down through the entire vadose zone into the groundwater. One of the most significant observations during the 2006 floods was that small floods (with water levels of more than 15 cm) yielded groundwater infiltration fluxes that are similar to those generated by large floods. Whilst high flood peaks may promote transmission losses as they flood more remote terraces of the river channel, they do not seem to have an enhanced contribution to the recharge of the alluvial aquifer itself. Rather, it is the flood duration within the active streambed that is important to the recharge process, suggesting that the nature of the flood (high, medium or low) plays a lesser role. The layered structure of alluvial sediments regulates the infiltration process of water into the aquifer and buffers the implied recharge capacity of high water heads during large floods. Nevertheless, large floods tend to last longer than small floods, which may again enhance their groundwater recharge capacity.

Table 3.14 Basic characteristics of the lower Kuiseb aquifer

Aquifer	Area (km²)	Groundwater volume (Mm³)	Avg. time to replenish (years)	Peak floods (m³/s)	Groundwater storage capacity (Mm³)	Sustainable aquifer yield (Mm³)	Water abstraction (Mm³)
Kuiseb Delta	2125	340-240	3 – 4	800 - 1000	14	7	5

Source: (Benito et al. 2007)

Data recorded during the 2006 flood season further indicate that a sequence of flows with 18 days total duration was capable of replenishing the shallow aquifer across the entire length of the middle-lower Kuiseb River and assisted in re-assessing the sustainable yield of the alluvial aquifer (Benito et al. 2007) (Table 3.14). It further underlined that current abstraction levels are within the sustainable yield of the aquifer given current recharge rates. Changes in demand for groundwater from the aquifer from e.g. the mining industry could however alter that situation rapidly.

(Benito et al. 2007) underline that such information is extremely important to IWRM planning in Namibia, because it can be understood by non-experts. In addition, compared to earlier attempts, it sets the boundaries of sustainable abstraction of groundwater in the middle-lower Kuiseb basin in a more precise and fairly transparent manner. Such information for many other aquifers in the country seems to be lacking or is not easily accessible to users.

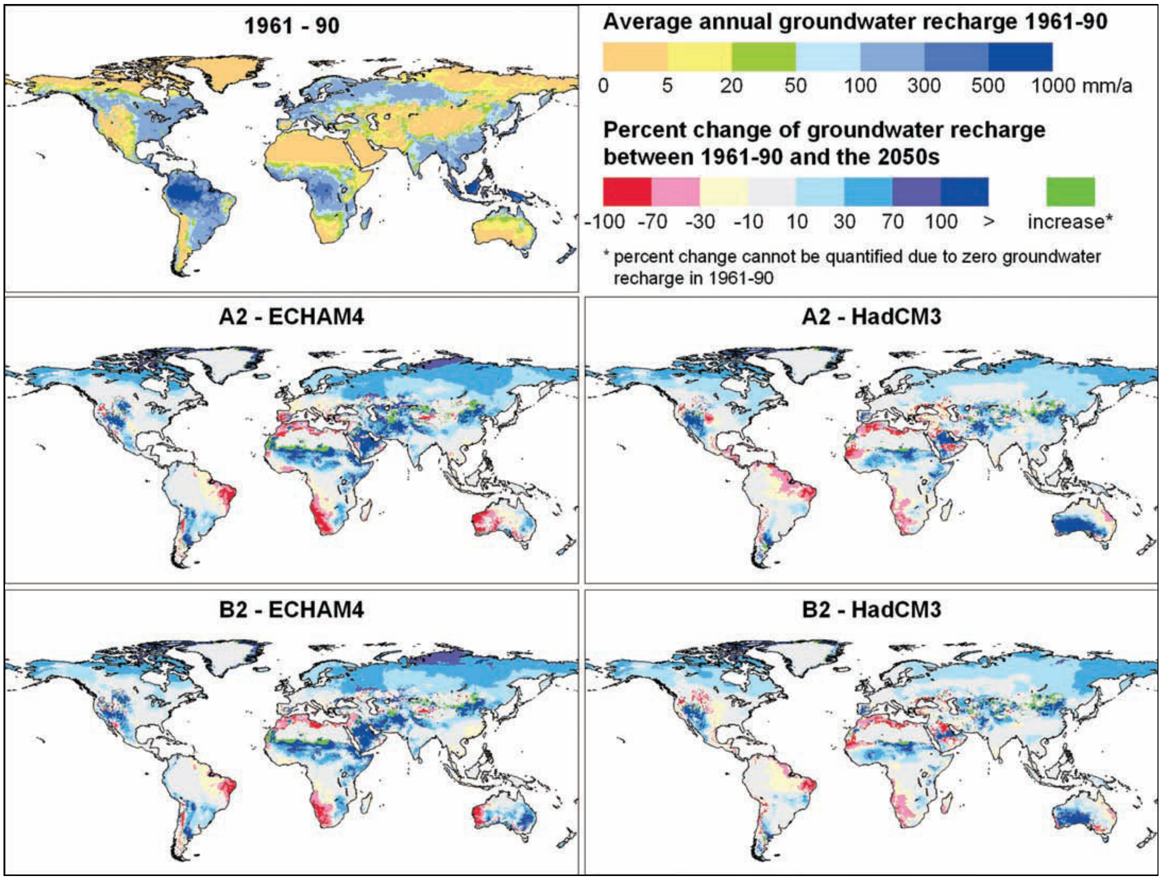
3.6.4 Vulnerability of Namibian groundwater systems to climate change

Although in general there is a strong correlation between rainfall and groundwater recharge, recharge to groundwater systems is difficult to measure. As the previous sections have partially illustrated it depends on a complex variety of factors, such as rainfall intensity, soil conditions, soil moisture, the slope or gradient of the surface topography, vegetation cover and land use, depth of the water table and characteristics of the underlying aquifer. This means that the same rainfall event can produce different amounts of recharge, not only for different hydro-geological environments, but also within similar zones (Christelis and Struckmeier 2001). Groundwater systems moreover respond more slowly to climate change than surface water systems as they have a longer lag time than surface water systems (Kundzewicz et al. 2007). Against this background it is not easy to make general statements about the vulnerability of groundwater systems to climate change.

At the global level attempts to model the impact of climate change on groundwater recharge have nevertheless been made. Figure 3.6 depicts the impact of climate change according to the SRES A2 and B2 scenarios for ECHAM4 and HADCM3. According to the HADCM3 simulation, groundwater recharge in major parts of south-western Africa, comprising

Namibia, is projected to decrease by more than 30% for both the A2 and B2 emission scenarios. There is again a considerable degree of uncertainty between climate models; the impact of climate change on groundwater recharge is more devastating according to ECHAM4, which predicts that recharge for both emission scenarios may be diminished by more than 70% across parts of Namibia, whilst recharge in other parts of the country might be reduced by 30 percent.

Figure 3.6 **Simulated impact of climate change on long-term average annual diffuse groundwater recharge. Percentage changes of 30 year averages groundwater recharge between present-day (1961 to 1990) and the 2050s (2041 to 2070), as computed by the global hydro-logical model WGHM, applying four different climate change scenarios (climate scenarios computed by the climate models ECHAM4 and HadCM3), each interpreting the two IPCC greenhouse gas emissions scenarios A2 and B2 (Döll and Flörke, 2005 in Kundzewicz et al. 2007)**

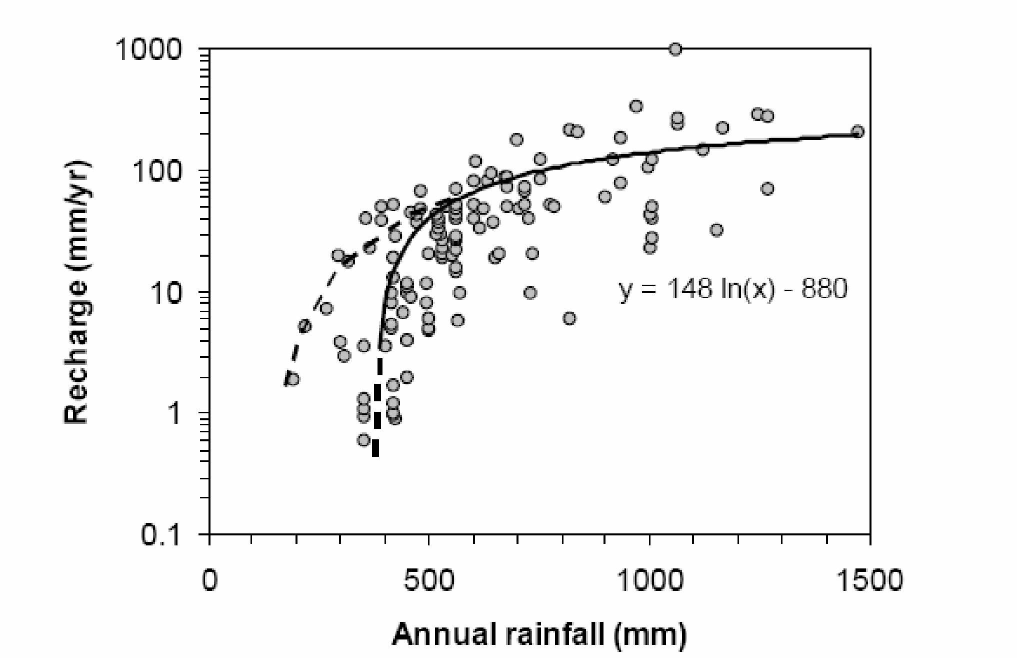


Source: (Kundzewicz et al. 2007)

In line with the above, it seems that scientists agree that a decline in groundwater recharge and resources would be expected over the semi-arid and arid regions of Southern Africa under currently accepted climate change scenarios (Cave et al. 2003; Kirchner 2003). Such general indications are based on straightforward rainfall – recharge relationships as a first attempt to assess the impact of climate change on groundwater resources, as shown in Figure 3.7. The graph depicts recharge rates as a function of annual rainfall for Southern Africa based on data from various studies in Botswana, South Africa and Zimbabwe, using different methods. The argument that is raised is that under a scenario of a warming global climate, increasing temperatures would result in decreasing precipitation over the central continental regions of Southern Africa, which in turn would lead to decreasing recharge rates and thus to depletion of groundwater resources.

Figure 3.7 illustrates what would happen to groundwater recharge in a location that currently receives about 500 mm rainfall per year, in a scenario that projects a decrease of mean annual rainfall, possibly by as much as 20%, i.e. to 400 mm. According to the graph, under current conditions about 40 mm/year of recharge should reach the local aquifer, but following this scenario by 2055 this would be substantially reduced to well below 10 mm per year. The figure further shows that groundwater recharge becomes negligible for rainfall lower than about 400 mm/yr, thereby possibly neglecting information of recharge of alluvial aquifers in ephemeral basins such as the Kuiseb River. The authors continue to explain that decreased recharge will lead to a considerable lowering of the groundwater table and is therefore likely to increase both drilling and pumping costs for groundwater users (Cave et al. 2003).

Figure 3.7 The relation between rainfall and groundwater recharge for Southern Africa



Source: (Cave et al. 2003)

Such general relationships between annual rainfall and recharge however obscure the fact that climate change not only affects the volume of rainfall, but also the frequency, duration and intensity of rainfall events, which also have an impact on recharge. The frequency of rainfall events will affect antecedent soil moisture conditions, as well as vegetation cover. How these factors interact in specific environments is often location specific and more difficult to predict. As part of this assessment an attempt should at least be made to consider the potential impacts on the different groundwater systems in the Caprivi, the Fish River Basin and the western alluvial aquifers.

In chapter 1 we have seen that there are signs of increases in convective rainfall in the late summer in Caprivi, Karas and the area around Grootfontein. Apart from parts of the Caprivi strip, groundwater recharge in the Caprivi is however informed by water seeping through the river beds of the major rivers that surround the region and not so much by rainfall. These rivers are perennial rivers and a reduction in drainage of more than 20% is expected according to (De Wit and Stankiewicz 2006). To what extent this might have further impacts for recharge of groundwater in the Caprivi is not clear at this stage. One should realize that although one may expect reduced stream flow in the future, it does not mean that the rivers will completely dry out. Groundwater is therefore likely to be recharged in the future, but possibly at lower rates.

Recent evidence suggests that recharge of groundwater in alluvial aquifers is related to the frequency and duration of floods in the ephemeral basins (see section 3.6.3). Whilst the lower end of Namibia's western ephemeral basins might benefit from increased coastal rains during summer around 2055, it may be more relevant to note that some of the major ephemeral rivers such as the Kuiseb and the Omaruru have their origins in central regions of Namibia. As we have seen in chapter 1 there are indications of increased convective late summer rainfall across the regions studied (Caprivi, Karas and Grootfontein). Moreover, the historic record of Windhoek also revealed signs of increased precipitation in recent decades. Hence, the ephemeral rivers that have their origins in central Namibia might possibly benefit from increased late summer convective rainfall under future climatic conditions. This in turn might possibly lead to slightly increased frequency and duration of floods in ephemeral rivers in the late summer months, with potentially positive implications for recharge of alluvial aquifers. This may however not be applicable to the ephemeral rivers that do not reach far into the interior of Namibia.

Such potentially positive impacts of increases in convective rainfall on groundwater recharge in alluvial aquifers may be counter-balanced by an anticipated increase in bush encroachment, especially in the central and north-eastern parts of Namibia (see also chapter 4). Recent studies in the Karst area of Namibia underscore that bush encroachment has a strong negative impact on groundwater recharge. This effect is expected to become worse under future climatic conditions (Bockmuehl 2007, personal communication).

As far as groundwater in the Fish River Basin in the Hardap and Karas regions is concerned, it is relevant to consider the impact of climate change on rainfall and runoff as discussed in earlier sections of this chapter. Although the models do not give conclusive direction, there are some signals that rainfall and runoff in the Fish River Basin might increase and become more regular towards the end of the 21st century, especially in the far South of the basin. If this is coupled with increased convective rainfall in late summer, increased event intensity and duration would be expected to lead to surface runoff and recharge. This might possibly have positive implications for the recharge of alluvial aquifers in sub-catchments in the far South of the basin. Increases in runoff are not expected to have a positive impact on recharge of secondary aquifers. Although one might in general expect that any increase in runoff would also have some positive effects for the recharge of aquifers, whether primary or secondary, the region is characterized by arid conditions with hard impermeable surfaces that generally do not allow much infiltration and recharge. Substantial increases in evaporation caused by temperature increases need to be taken into consideration. Increases in rainfall in successive years may further lead to increases in the vegetation cover, which contributes to reduction in runoff over much of the regions. These various factors may counteract suggestions of increased aquifer recharge in secondary aquifers.

As there are still many uncertainties concerning changes in rainfall and runoff in Southern Africa in general and Namibia in particular, deducting the implications for groundwater recharge in specific regions of Namibia, such as the Caprivi, the southern regions and the Omarurua and Kuiseb, is an exercise of very preliminary nature. As such further studies are required to create a better understanding of the relation between climate change, runoff and groundwater recharge in Namibia.

Table 3.15 Overview of the vulnerability of water resources to climate change: impacts of changes in rainfall on groundwater recharge and non-climatic stressors

Climatic Issue	Model agreement	Direction of change	Primary impact	Secondary Impacts
Rainfall / groundwater recharge	Global models agree on direction of change, not on magnitude. (Only limited amount of work has been undertaken so far).		Reduction in recharge of 30-70%	• Increase in pumping costs and reduced potential for boreholes critical to livestock production and management in Namibia • Lower water table in alluvial aquifers with negative impacts on water levels in springs, wells and waterholes. Affects riparian vegetation, animals and people.
CO_2	Yes	Shift in dominant vegetation type from grassy savannah to arid and semi-arid shrubland	Increase in bush encroachment in North-eastern quadrant of Namibia	Negative impact on groundwater recharge
Non-climatic stressors (crosscutting): see also section 3.3				
• Population growth and economic development: water demand will surpass currently installed abstraction capacity between 2015 and 2020				
• Expected increase in demand for water in the mining sector • A considerable increase in demand for water in irrigated agriculture				
• Insufficient water demand management in small and medium sized towns and villages; • Tariff setting insufficiently focused on ‘conservation tariffs’ and matters of equity				
• IWRM / Basin Management not implemented in all basins (committees not yet operational) • Poverty reduces the capacity and willingness to pay for scarce resources				

3.7 Conclusion

Namibia is a water scarce country where potential evoparation exceeds precipitation. The semi-arid conditions make Namibian wetlands vulnerable ecosystems, where the impact of human activities usually exceeds the natural impacts. Even without human influence, climate variability and climate change will bring about added stress to Namibia's water resources and wetlands. Global warming will contribute to a change in temperature of 1°C to 3.5°C in summer and 1°C to 4°C in winter in Namibia, which will lead to increases in evaporation and evapotranspiration in the range of 5-15%.

Changes in rainfall patterns over Namibia, Zambia and Angola will affect runoff and drainage in perennial rivers in northern Namibia. A reduction of 10-20% in rainfall by 2045-2065 over the catchments of the Zambezi, Kavango, Cuvelai and Kunene rivers is expected to lead to a reduction in runoff and drainage in these river systems by +/- 25%. In the southern regions of Namibia rainfall is expected to increase towards the period 2080-2100, with the most likely increases in the late summer months, which appears to lead to increases in runoff with positive effects for safe dam yields in the far South of the Fish River catchment. Signals are however less clear for runoff and dam yields in the sub-catchment of the Hardap dam, which implies that the results must be interpreted carefully and that further research to better understand rainfall-runoff relationships under climate change may be required. In general, groundwater recharge is expected to suffer a reduction of 30-70% across Namibia; a potential exception could be found in the recharge of alluvial aquifers that have their origins in central areas of Namibia, where more late summer convective rainfall can be expected by the mid of the 21st century (a trend that can moreover already be observed).

Such changes increase the vulnerability of wetlands in Namibia. The wetlands least likely to be adversely affected are those perennial river systems in the north-east that are dependent on higher rainfall outside of Namibia and whose flow is not restricted by impoundments. Those most likely to be affected are the Kunene River, the Cuvelai system, the westward flowing ephemeral rivers and numerous seeps and springs. The mouths of the Kunene and Orange rivers may be affected, with possibly serious implications for their qualifications as Ramsar sites. Floodplains in the Caprivi and oshana's in the Cuvelai remain particularly vulnerable, as smaller areas will be inundated and because they may dry out sooner due to increased evaporation. The Okavango delta may be strongly affected in similar ways, as a result of which it may potentially shift to a seasonal river. Overall, these impacts lead to reduced productivity of floodplains and floodplain lakes, amongst others characterised by disrupted breeding/growth cycles of invertebrates, fish and flora, as well as reduced ecosystem services such as water retention, flood attenuation and water purification. The latter may again negatively affect rural livelihoods and tourism. On the positive side, with reductions in drainage of major river systems, one may expect a reduction in flood damages.

Any adverse change to the aquatic systems will usually be compounded and exacerbated by human impact. Against this background it is noteworthy that water demand is expected to exceed the currently installed abstraction capacity by 2015, due to population growth and economic development. In fact a doubling of the demand for water is expected in the next 10 years, mostly due to increased irrigation requirements, even though water productivity in (irrigated) agriculture is considerably lower than in other sectors. In relation to changes in global economic development, the mining sector may also experience growth that leads to further increases in demand for water, not foreseen earlier.

Due to such increases in demand Namibia has reached its carrying capacity with regard to water in many areas of the county, or will exceed it in the near future. In view of added stress on water resources caused by climatic changes, it will become more important to carefully manage demand for water and to devise ways of storing water so that it is not subject to evaporation. In this regard Namibia could build on its vast experience with IWRM, conjuctive use of surface- and groundwater resources and recent experience with subterranean storage. Demand management concerns the management of domestic demand in municipalities, industrial or mining demand, as well as the agricultural sector. Livestock numbers and their water demand should be closely monitored. In view of reduced drainage in perennial rivers the sustainability of large irrigation projects that use large amounts of water must be reviewed. Alternatively resources should be allocated to introduce more effective irrigation techniques such as drip irrigation and crops that add more economic value. Ways in which these water demand can be managed are further discussed in the final chapter of this report.

With increased impoundment of ephemeral rivers and groundwater abstraction, it is furthermore essential to monitor groundwater levels more strictly. Ecosystem services in ephemeral rivers could further be supported by releasing water from dams to allow sufficient recharge to sustain the riparian vegetation. In addition it would be relevant to monitor the condition of riparian woodlands and to introduce measures to prevent the loss of woodlands, as it is not possible to restore a riparian woodland once it has died.

4 Vulnerability of the agricultural sector to climate change

4.1 Introduction

This report has this far covered the Namibian climate scenarios for the century and discussed some of the socio-economic vulnerabilities the sectors of agriculture and water face in lieu of climate change, both at national and regional level.

This chapter focuses on the vulnerability of the agricultural sector from the biophysical point of view, looking at the effect of the changing climate on crop responses in terms of yields and planting windows, as well as the impact climate change has on grazing availability, livestock production, water demand and animal diseases. A discussion of the sectors role in the economy, as well as a brief discussion of crop and livestock farming in the Karas and Caprivi region, precede the findings of the impact climate change *per se* is likely to have. The purpose of this discussion is to realize the dualism of the sector, and highlight in particular the challenges the smallholder farmers face.

4.2 Role of the agricultural sector in the Namibian economy

The 2001 Population and Housing Census registered 67% of Namibians as rural dwellers. The main source of income for most of the rural population was subsistence agriculture. In addition, many of those registered as urban dwellers live in small towns and are also full-time, or part-time/ weekend farmers. Though the percentage of rural dwellers has dropped by 5% from 1991 to 2001, the number of people attempting to make a living of a finite resource base is consistently rising. Agriculture can expand, either through intensification or mostly through the development of very marginal areas with severe agro-ecological constraints. Incomes per capita from agriculture are falling as current demographic trends continue. Yet, agriculture as a sector is the 6th largest contributor to Namibian GDP and is considered by many as a sector that should be an engine for economic growth.

Indeed agriculture is an important pillar of the formal economy and remains the basis of the livelihoods of the majority of the country's population. Including meat processing, the sector ranks nationally only behind government services; mining; finance, real estate and services, wholesale and retail trade; and manufacturing, in terms of its contribution to GDP at 6th position as mentioned above. It is notable however that its relative contribution to GDP is declining. In the years 2000 to 2004 the sector contributed 5.02% to the GDP on average (Namibia Agronomic Board 2006a). While opportunities for sectoral growth are still available, for example in the irrigation sub-sector, through increased livestock production and marketing in the northern regions, and greater value added to livestock inside the country, these opportunities are limited due to agro-ecological constraints.

The agriculture sector's mission, as defined in the second National Development Plan (NDP2), is to improve food security at both household level and nationally and to create employment opportunities. This will contribute to the national goals of sustainable and equitable economic growth.

4.2.1 A dualistic sector

A key feature of Namibian agriculture is its dualistic nature. As such the commercial sector has contributed 3,5% on average to the economy, whilst the figure is 1,5% for the communal sector (average figures for both subsectors during the period 2000 to 2004 (Namibia

Agronomic Board 2006b). In communal land tenure areas, agriculture provides vital income and food for the poorer sections of the community based on low-input low-output farming systems, while in the freehold areas, commercial farming on large ranches provides a good source of income to a small number of commercial farmers, exporting their produce through sophisticated marketing systems to the EU and other countries. This dualism is underpinned by significant differences in access to: land, markets, credit, inputs, public services, and farm management skills. The primary role of communal area agriculture is in providing socio-economic security until such time as other sectors of the economy are able to provide more jobs and incomes. Current land use practices do not promise increased production, and the expectation of explicit economic growth generated from this part of the economy has to be small.

This dualism also affects institutional capacity. Small farmers are relatively voiceless and the few institutions representing them generally lack capacity. On the contrary commercial farmers are well organised with strong institutions lobbying for their interests. The lack of a strong voice amongst smallholder farmers will be concern when trying to shape a future cognizant of climate change.

The agriculture sector as a whole recorded growth (in terms of its contribution to Gross Domestic Product at constant 1995 prices) of 0.7 per cent in 2002, while in 2001 its contribution declined by 14.9 per cent. The sector's changes are depicted in Table 4.1 below.

Table 4.1: Agricultural sector contribution to GDP (at constant 1995 prices)

	2000	2001	2002	2003	2004
Agriculture & Forestry	4.7	-14.9	8.5	3.6	1.5
Commercial	31.1	-9.2	22.7	4.5	-9.1
Subsistence	-20.7	24.0	-0.5	0.9	32.9

Source: (Republic of Namibia 2006c)

In terms of volumes of production (irrespective of prices) Table 4.2 presents changes relative to a baseline of 1995 (as such 1995 =100).

Table 4.2: Agricultural sector production volume (relative to 1995 prices)

	2000	2001	2002	2003	2004
Agriculture	118.9	91.9	97.2	95.4	87.4
Commercial	99.6	118.9	126.8	109.8	89.9
Communal	166.4	42.0	67.3	60.4	80.3

Source: (Republic of Namibia 2005a)

Although the Government has specific policies in place to address the dualism in the sector huge disparities continue to exist with the communal sector struggling to live up to expectations, as the review of NDP2 showed.

4.3 Crop production in the Namibian economy

Crop production plays an important role for household food security, particularly in the northern parts of the country. Its share to the formal agriculture sector contribution is less than 10% though (Republic of Namibia 2004). The impact of Climate change on maize and pearl millet production is investigated in more detail considering that these form the backbone of domestic staple foods.

4.3.1 Production of white maize in Namibia

Maize is the most produced and most consumed cereal in southern Africa, and contributes 40% of the calories consumed in people's diets. (S.T. Kandji 2006)

In Namibia, white maize is produced under irrigation and dry-land conditions. Dry-land maize is planted in the following areas:

- Maize Triangle (Otavi–Grootfontein–Tsumeb area)
- Otjizondjupa Region (Hochfeld, Otjiwarongo)
- Omaheke Region (Gobabis and Summerdown)
- Caprivi and Kavango Regions (Namibia Agronomic Board 2006a)

Dry-land producers normally commence with the planting process towards the end of November each year, after the first rain showers. The main marketing season commences in May the following year, and ends when the maize harvested between 1 May and 15 August is sold and milled.

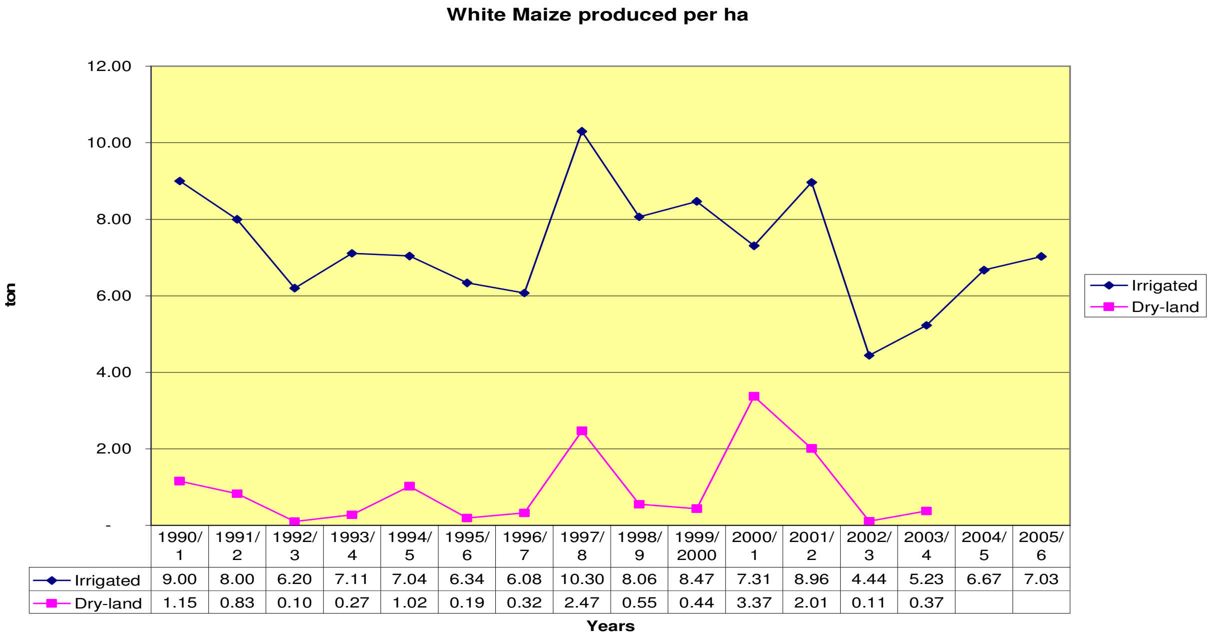
Small-scale farmers in the Kavango also plant white maize under dry-land conditions, but it is mainly utilised for domestic consumption.

Irrigation maize is produced in the following areas:

- Maize Triangle (Otavi–Grootfontein–Tsumeb area)
- Near Mariental (Hardap Irrigation Project)
- Stampriet and Gobabis areas
- Kavango Region (the Mashare, Musese, Sarasungu, Shadi Kongoro, Shitemo, and Vungu Vungu Irrigation Projects)
- North-central Regions (Etunda Irrigation Project) (Namibia Agronomic Board 2006a)

Most irrigation producers plant in cycles. Maize planted in August/September each year will be harvested in February/March the following year.

Figure 4.1: Annual per/ha production of White maize in Namibia since Independence



Source: adapted from (Namibia Agronomic Board 2006a)

Average dryland production per ha in the past 14 years (data for 2004 to 2006 could not be used due to the absence of the total ha planted upon inclusion of Caprivi produce marketed) has been 940 kg per ha (7260 kg per ha under irrigation).

4.3.2 Production of pearl millet (mahangu) in Namibia

Pearl millet, also known by its local name, mahangu, is a subsistence dry-land cereal crop and the major staple food crop produced for a large number of people, especially in the Northern Communal Areas (NCA), as well as the Caprivi and Kavango Regions.

This crop is highly adapted to low rainfall and the prevailing soil conditions in the Oshikoto, Ohangwena, Omusati, Oshana and the Kavango regions. For many years, small-scale farmers have survived on the low yields generally obtained form mahangu.

Production figures on pearl millet are obtained from both the commercial and communal sector (Table 4.3). The communal sector statistics are based on estimates of the Early Warning Division in the MAWF (as in Table 4.4, Table 4.5 and Table 4.6 below), and some statistics as reported in the Annual Agricultural Survey reports (as in Section 4.3.3 below).

Table 4.3: Mahangu production on title-deed farms

	Area planted (ha)	Harvested crop (t)	Price (N$/t)
Commercial	412	990	1,672

Source: (Namibia Agronomic Board 2006a)

Table 4.4 indicates the surface area planted for millet and sorghum, as estimated by the MAWF early warning unit.

Table 4.4: Millet and Sorghum hectarage planted annually

	2000	2001	2002	2003	2004
North Central	255,500	236,900	202,000	252,500	252,100
Kavango	15,000	10,200	12,300	13,800	16,700
Caprivi	8,500	5,700	5,400	5,600	5,200

Source: (Republic of Namibia 2005a)

The same unit in the MAWF estimates the production for a given year, results of which are reflected below (Table 4.5).

Table 4.5: Production figures for Millet and Sorghum (tons)

	2000	2001	2002	2003	2004
North Central	74,000	65,200	30,800	54,100	74,400
Kavango	5,700	3,300	3,300	2,800	4,300
Caprivi	3,900	1,900	1,100	1,300	1,800

Source: (Republic of Namibia 2005a)

This means that the following yields (Table 4.6) were obtained during the period 2000 to 2004, with an average yield of 280 kg per ha in the communal areas (compared to 2400 kg per ha in the 2005/06 in the commercial area). Despite being a staple crop in central northern Namibia, the production per ha is very low compared to global figures. Limited use of fertilizers (as in Figure 4.5 below) and variable rainfall provide a partial explanation.

Table 4.6: Millet and Sorghum yields (t/ha)

	2000	2001	2002	2003	2004
North Central	0.29	0.28	0.15	0.21	0.30
Kavango	0.38	0.32	0.27	0.20	0.26
Caprivi	0.46	0.33	0.20	0.23	0.35

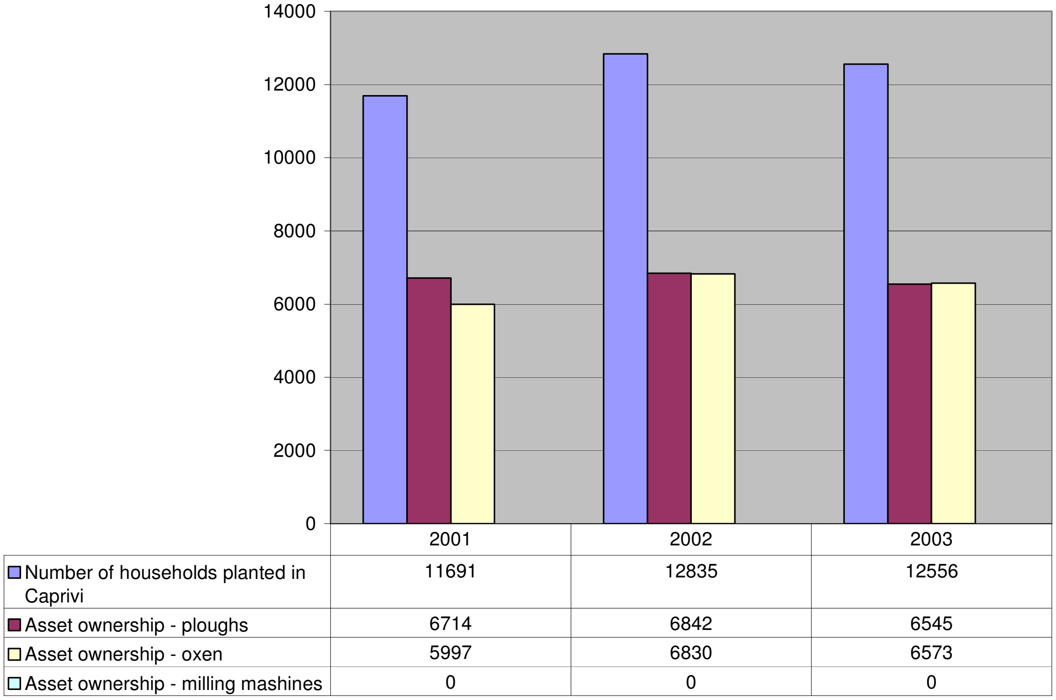
(Source: (Republic of Namibia 2005a)

4.3.3 Crop production in Caprivi

The Annual Agricultural Surveys (Republic of Namibia 2004b) provide useful information specifically for the Caprivi region. As such Figure 4.2 below indicates that from approximately 12,000 households in Caprivi producing crops, only half own such important implements such as a plough, or a draught animal. Milling machines, which are found by their thousands in the central northern regions (Republic of Namibia 2004b) seem not to have been purchased in Caprivi.

Figure 4.3 and Figure 4.4 clearly indicate the low level adoption of improved seed varieties, both amongst Mahangu and Maize producers. The findings regarding fertilizer application, or even the use of manure to improve yields, are similarly low (Figure 4.5). Throughout the assessment period the Annual Agricultural Surveys indicate that female farmers are using significantly less of the improved seeds, as well as chemical fertilizers, than their male counterparts.

Figure 4.2: Number of crop-producing households and asset distribution (Caprivi)

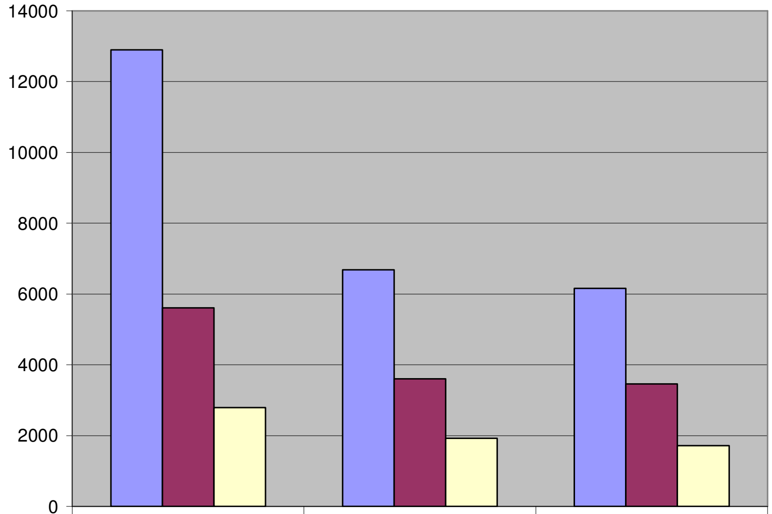


	2001	2002	2003
🟦 Number of households planted in Caprivi	11691	12835	12556
🟥 Asset ownership - ploughs	6714	6842	6545
🟨 Asset ownership - oxen	5997	6830	6573
□ Asset ownership - milling mashines	0	0	0

Source: adapted from (Republic of Namibia 2004b)

Low-input/ low-output systems are common throughout Africa, and many reasons for this choice exist. This system works as long as land is relatively abundant, and food stuff is locally available. As population pressure increases, urbanization and climate change occurs the pressure to intensify per ha yields will grow. The figures in this section suggest that significant scope exists to pursue this intensification pathway, but structural questions need to be addressed such as the availability of seeds (varieties adapted to shortened growth seasons), fertilizers, and machinery. Skills of farmers would need to be aligned along with new techniques, and the huge irrigation potential of the region could be harnessed (if done in a sustainable manner). The rather high share of female-headed households, and the additional stress the HIV/Aids pandemic puts on labor availability, warrants the adoption of labor-saving techniques.

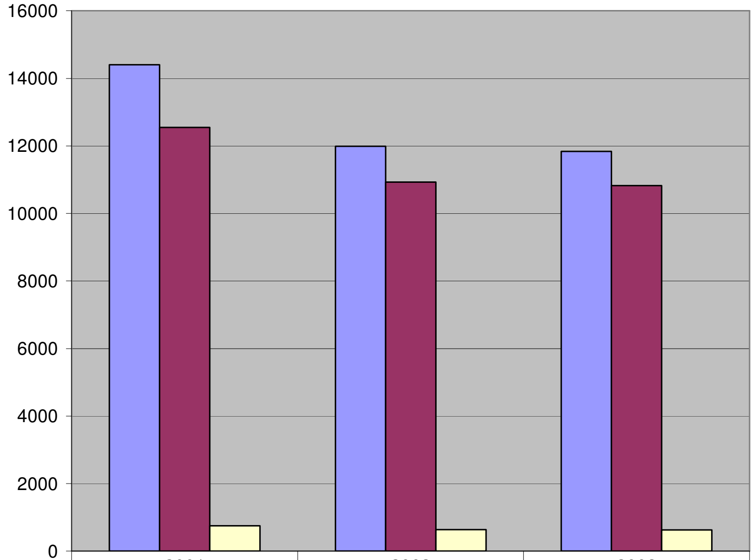
Figure 4.3: Seed choice of Mahangu farmers



	2001	2002	2003
🟦 Total ha planted for mahangu	12901	6685	6163
🟥 Ha of Mahungu planted, traditional seed	5607	3607	3455
🟨 Ha of Mahangu planted, improved seed	2792	1923	1715

Source: adapted from(Republic of Namibia 2004b)

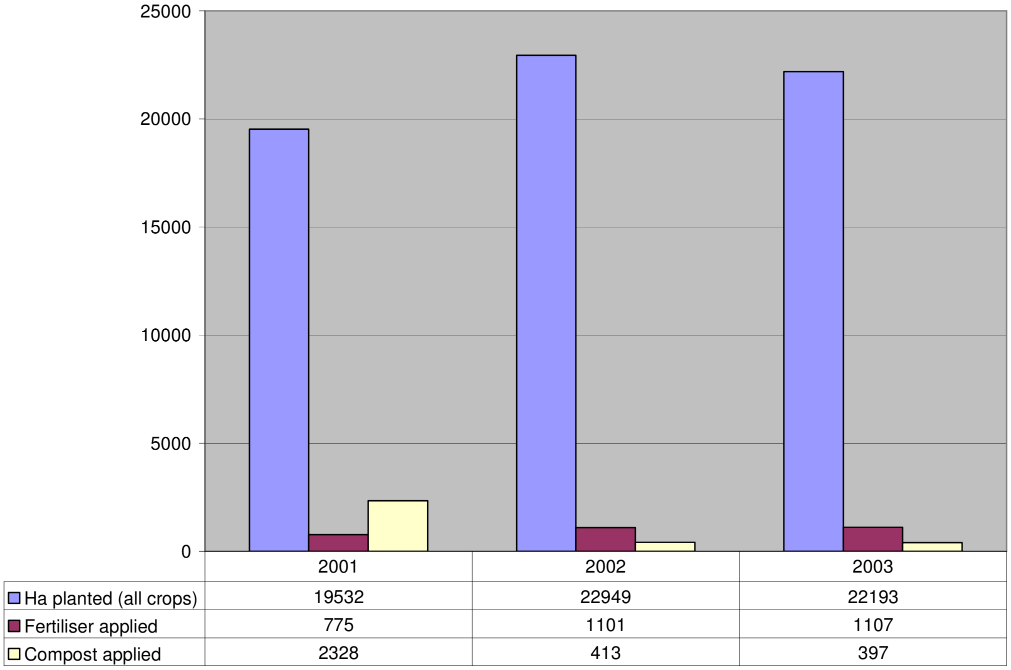
Figure 4.4: Seed choice for Maize farmers



	2001	2002	2003
🟦 Total ha planted for maize	14395	11982	11835
🟥 Ha of Maize planted, traditional seed	12550	10927	10821
🟨 Ha of Maize planted, improved seed	749	628	626

Source: adapted from (Republic of Namibia 2004b)

Figure 4.5: Fertiliser and compost application in Caprivi

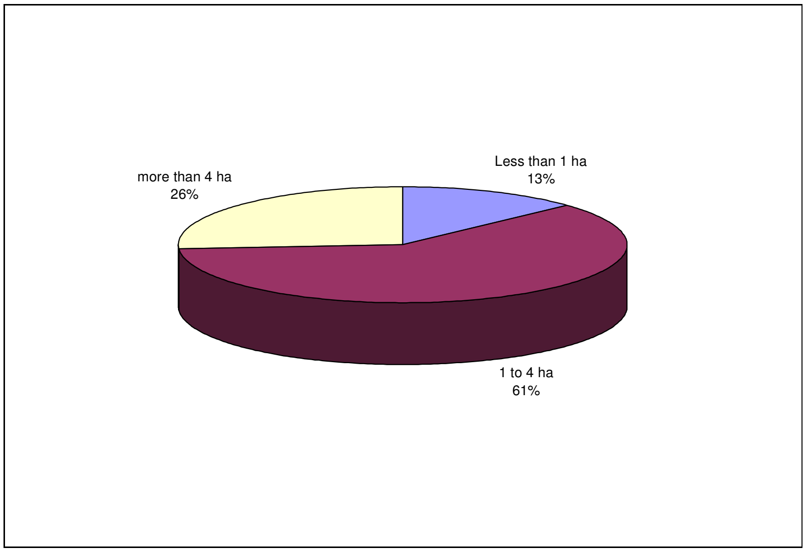


	2001	2002	2003
🟦 Ha planted (all crops)	19532	22949	22193
🟪 Fertiliser applied	775	1101	1107
🟨 Compost applied	2328	413	397

Source: adapted from (Republic of Namibia 2004b)

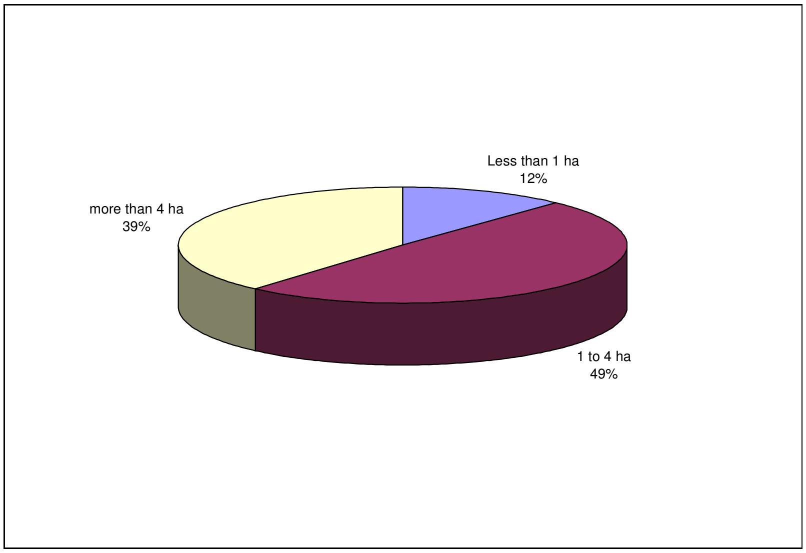
Female farmers have less access to the largest fields, with only a quarter of the female producers cultivating fields larger than 4 ha compared to nearly 40% of male farmers (Figure 4.6 and Figure 4.7). Most Caprivians crop on fields between 1 and 4 ha in size.

Figure 4.6: Area cultivated by female Caprivians



Source: adapted from (Republic of Namibia 2004b)

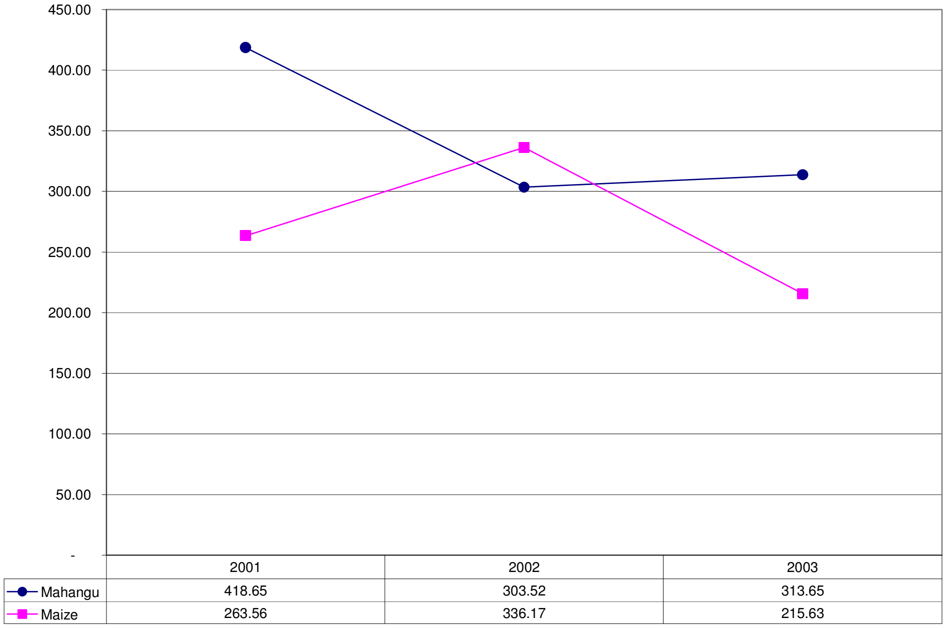
Figure 4.7: Area cultivated by male Caprivians



Source: adapted from (Republic of Namibia 2004b)

The low-input/ low-output strategy pursued by Caprivian smallholders also results in distinctly low yields for both crops (Figure 4.8). Mahangu yields in the region have averaged at 345kg per ha for the early part of the century (compared to 2,4 tons amongst commercial producers), and 272 kg per ha for Maize (compared to 940 kg per ha amongst commercial producers).

Figure 4.8: Average yields of Mahangu and Maize production by communal producers in the Caprivi region



Source: adapted from (Republic of Namibia 2004b)

4.3.4 Imports and self-sufficiency

To reduce the value of imports Namibia pursues a policy of import substitution (i.e. producing more of the imported products locally). In the case of maize and wheat grain Namibia imposes import restrictions to ensure that grain is imported only after commercial production has been purchased by millers (the declaration of mahangu as a controlled crop to have equal status has just been passed). Grain imports vary annually in line with domestic production, which is mainly related to rainfall. Grain imports in the reporting period are presented in Table 4.7.

Table 4.7: Grain imports in Namibia (Figures for Mahangu are not available)

Import	2000 (t)	2001 (t)	2002 (t)	2003 (t)	2004 (t)	2005(t)
White Maize	62,958	80,268	85,886	88,080	87,434	76,534
Yellow Maize	28,289	No info	61,53	52,024	29,839	37,156
Wheat	49,317	41,695	64,748	65,108	79,888	73,411
Totals	140,564	121,963	150,634	205,212	197,161	187,101

Source: (Namibia Agronomic Board 2006a)

Grain imports vary in line with domestic production. The balance of trade for staple grains is partly determined by rainfall because the bulk of production is rain fed. In years of good rainfall, notably as 1996/97, Namibia achieved approximately 69% grain self-sufficiency (Table 4.8). This has declined since then.

Table 4.8: Grain self-sufficiency in Namibia

Year	Total grain production ('000 ton)	Total domestic demand – production + imports average ('000 ton)	Per cent grain self-sufficiency
1996/97	183	265	69
2000/01	121	265	46
2001/02	73	265	28
2002/03	102	265	38

Source: (Republic of Namibia 2004b)

The majority of white maize consumed in Namibia remains an import good (Table 4.9):

Table 4.9: Statistics of white maize import and consumption

Year	Imports (ton)	Total white maize consumption (ton)	% own production of total consumption
2000/1	62,958	92,728	32.10
2001/2	80,268	103,078	22.13
2002/3	85,886	109,117	21.29
2003/4	88,080	109,524	19.58
2004/5	87,434	143,208	38.95
2005/6	76,534	113,000	32.27

Source: adapted from (Namibia Agronomic Board 2006a)

Potential for increasing grain production, and thus reducing the need for imports, exists by means of irrigated production and by increasing production of rainfed small grains (sorghum and millet). On the other hand, maize production, which accounts for an average of 30% of domestic grain production, may in future be threatened by trade liberalisation measures under the SADC Trade Protocol.

4.4 Livestock production in the Namibian economy

Livestock production is the driver of the agricultural economy, and meat is one of the major export goods of Namibia. In the period 2000-2004 the livestock sector has, on average, contribute 89,3% to the sectors contribution to GDP (Table 4.10). (Republic of Namibia 2004)

Table 4.10: Livestock sub-sector contribution to Agricultural GDP

	2000	2001	2002	2003	2004
Livestock					
Commercial	53.6	73.3	73.7	71.4	62.8
Communal	38.9	14.9	17.6	16.7	24
Total	**92.5**	**88.2**	**91.3**	**88.1**	**86.8**

(Source: (Republic of Namibia 2005a)

The predominant sub-sectors are cattle and sheep/goat production. The table below clearly shows that although cattle dominate, at least in the commercial sector smallstock plays a significant role in the economy (Table 4.11).

Table 4.11: Share of large- and small stock sub-sectors in livestock contribution to GDP

	2000	2001	2002	2003	2004
Livestock					
Commercial	53.6	73.3	73.7	71.4	62.8
Cattle	19.8	43.1	32.1	45.4	33.9
Sheep	18.3	15.6	27.3	18.7	15.2
Communal	38.9	14.9	17.6	16.7	24
Cattle	no disaggregated data available				
Sheep					

(Source: (Republic of Namibia 2005a)

As noted in Table 4.12 the volatility of the sector due to climatic variability is easily demonstrated. Table 4.12 expresses volume of production (constant at 1995 prices) in the period 2000-2004. Figures in the commercial sector are less volatile and have actually demonstrated near-permanent growth, especially in the smallstock sector.

Table 4.12: Livestock sector volumes of production (constant at 1995 prices)

	2000	2001	2002	2003	2004
Livestock					
Communal	210.9	- 35.7	18.9	- 18.6	7.6
Cattle	128.5	- 17.4	- 46.9	- 25.9	42.0
Other	- 150.5	44.5	- 269.7	- 50.3	158.3

(Source: (Republic of Namibia 2005a)

At the national level cattle numbers in the commercial areas are around 850 000-900 000, whilst in the communal area the total number of cattle is ~ 1, 5 Million.

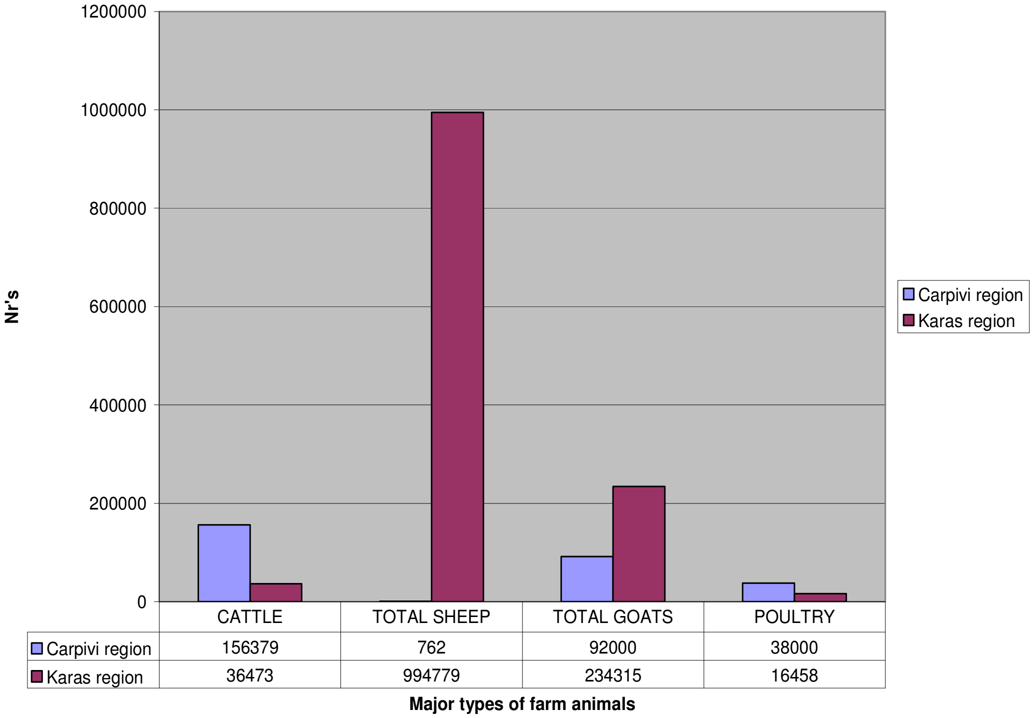
The national totals for karakul sheep just exceed 200 000; Dorper are the dominant sheep breed with totals of about 1 700 000, whilst about 700 000 heads of other breeds are found.

The commercial sheep herd exceeds the communal numbers at an given time by a factor of between 6 and 10.

Boer goats are the single largest goat breed with about 950 000, but an equal amount of other goatbreeds exist. The communal goat sector exceeds the commercial one by a factor 3.

Directorate of Veterinary Services (DVS) census data was used to produce the graph below (Figure 4.9), which indicates the difference in livestock numbers between Caprivi and Karas region (in 2006). The importance of cattle vs. smallstock differs markedly. Access to this livestock and the associated rangelands is restricted. In the Karas region, 62% of the population does not have access to rangelands, two-thirds of the population has neither access nor ownership of goats and more than 80% are excluded from sheep and cattle production according to the NHIES (Republic of Namibia 2004). In the Caprivi region, in comparison, 74% of the population either own or have access to cattle, and more than 70% have access (albeit communal) to grazing land.

Figure 4.9: Quantities of livestock types in the Caprivi and Karas region



	CATTLE	TOTAL SHEEP	TOTAL GOATS	POULTRY
■ Carpivi region	156379	762	92000	38000
■ Karas region	36473	994779	234315	16458

4.5 Cost of not adapting in the agricultural sector

The IIED (International Institute for Environment and Development Environmental Economics Programme) (Reid et al. 2007) predicts a decline of between 1,1% and 3,1% in Namibian GDP, based on a 'best-' and 'worst-case' scenario for the country in the coming 20 years. The activity share of cereal production is likely to decline by between 8,4% and 17%, livestock production is predicted to decline between 19% and 48,4%, whilst traditional (subsistence) agriculture is likely to suffer a decline between 33,5% and 74,6%. Commercial crop production, based on expectations resting on the Green Scheme, is suggested to increase by between 10,2% and 1,3% respectively for the two scenarios. These simulations give an indication of what would happen to the economy if no adaptation would take place and the full brunt of climate change was felt[4]. These losses are valued at between 1,5% and 3,5% of GDP (N$ 500 to N$ 100 Million respectively), with the communal farming sector hardest hit, further contributing to income inequality in Namibia.

4.6 Impact of climate change on the Namibian crop sector

4.6.1 Introduction

It has been mentioned that a major problem for a vulnerability and adaptation assessment at the local level is the lack of knowledge about exactly *what to adapt to*. In order to gage the combined effect of changes in rainfall and temperature on expected yields, the use of crop models for specific crop producing areas was employed with assistance from the Department of Agriculture.

4.6.1.1 Issues and uncertainties

Projected climate data for the middle of the 21st century was needed to run the crop models. The sources of such data are General Circulation Models (GCMs), though they have limited applicability for regional assessments of change. There are several reasons for this inadequacy: on the one hand, the spatial resolution of coupled atmosphere-ocean GCMs is too coarse to assist decisions at the local level, particularly in areas where topography is varied. Similarly, while GCMs are considered as fairly reliable in terms of projected changes in average values at the regional scale, they may have limited capacity to project aspects of the climate that are essential to understand for a farmer e.g. potential changes in the variability of the rainy season's onset, or increased frequency and intensity of dry spells that can destroy crops if they occur at critical stages of plant growth.

A further issue arises due to the long-term projections made under climate change i.e. typically for the 2050-2100 period. Whilst this is sometimes necessary to project changes in rainfall beyond those expected from natural variability, other variables such as temperature are already changing in the observed record. There is therefore a discontinuity in climate information that can inform adaptation and vulnerability assessments in the present (using observed climate) and that which can be used for the far future (GCM or downscaled projections). A comparison of observed and projected change is therefore necessary to identify vulnerabilities that are already facing increased stress and prioritise adaptation options that tackle these stresses. On the other hand there may be projected future changes that are not evident in the observed record, suggesting that these changes can be expected in the future. Or there may be observed changes that are not projected for the future but are evident in the observed record, suggesting that such changes are either due to natural variability or are not possible to model given the current set of GCMs.

For the purpose of crop modelling it was agreed to aim for mid-century changes, and a window of 2046 to 2065 was chosen.

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[4] The model does however incorporate increased irrigation (alias the Green Scheme), and shows that this adaptation measure will not be enough to off-set the impact of climate change in the rural economy.

4.6.1.2 Quality of climatic data

Observed daily climate data (obtained from the Namibian Meteorological Services) were tested for homogeneity by the CSAG using the Rhtest software. Before homogeneity testing the data was set to missing values if any of the following were true:

- Daily precipitation negative or > 450 mm
- Minimum temperatures > maximum temperatures
- Maximum temperatures > 55 °C

All the data was found to be of good quality with no changes in homogeneity that were likely (from visual inspection) due to environmental (e.g. site situation) or instrumental changes.

The data were then used primarily to analyze climatic trends over the past 40 years, in particular onset and cessation of the rains, and putting season lengths in the context of particularly maize farming, and carry out more detailed crop modelling depicting the potential future yields and planting windows for both maize and millet.

Past trends in temperature and rainfall data were explored first before embarking on crop modelling. Past trends allow for a better understanding of processes shaping climate change, but are by no means a guarantee for the future.

4.6.2 Historical trends in the duration of the agricultural growing season

Trends in the start and the end of the rainy season are analysed, and their combined effect on seasonal length explored and put into the context of growing maize in Namibia. The trends build on observations from the early 1960's onwards. The illustrations were produced by the CSAG.

Figure 4.10: Trends in planting dates/ onset of the season (days per annum)

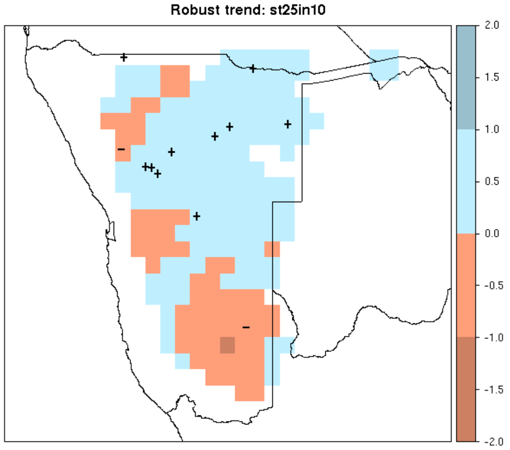

Figure 4.10 indicates the start of the season (suitable planting dates defined as 25 mm precipitation in 10 days). Coloured background indicates trends as derived using kriging[5], "+"/"-" indicates stations where statistically significant trends (at the 90% significance level) were observed. It can be seen that trends towards the northeast where the major agricultural zones are located have been later starts to the growing season; with the onset delayed by roughly half a day per year (thus about 20 days later at the start of the 21st century).

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[5] **Kriging** is a group of geostatistical techniques to interpolate the value of a random field (e.g. the elevation Z of the landscape as a function of the geographic location) at an unobserved location from observations of its value at nearby locations (http://en.wikipedia.org/wiki/Kriging)

Figure 4.11: Trends in cessation since 1960 (days per annum)

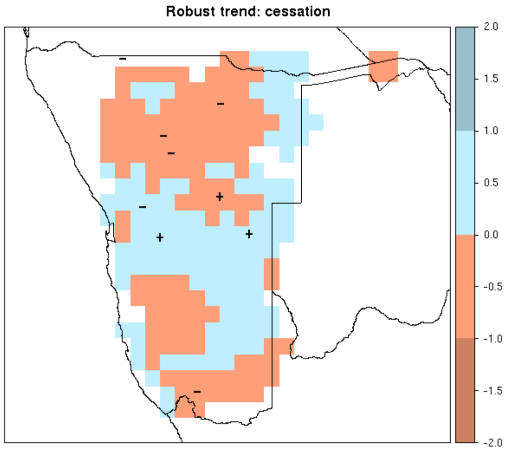

Figure 4.11 presents the trends in cessation of the rainy season since 1960; the rainy season ends later in the central northern regions and in the Caprivi strip. There are only some pockets where rainfall came earlier in the last 40 years. A combination of the tendency for later starts and the indicated earlier cessation leads to the trends for a reduction in the seasonal duration seen in Figure 4.12 below.

Figure 4.12: Trends in seasonal duration (days per annum)

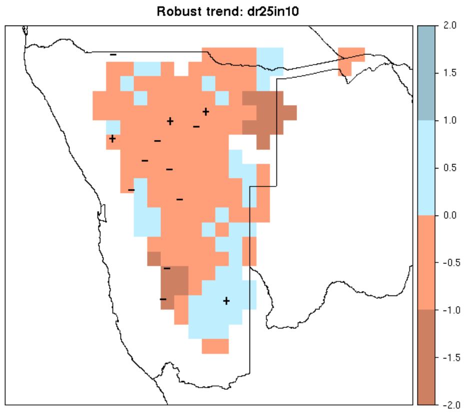

Figure 4.12 indicates that the season has become shorter each year over the 40-year period in most parts of northern central Namibia, and the signal is repeated in Caprivi. The exceptions to this pattern are the areas around Rundu and pockets in the south. The general trend for a shorter seasonal duration could lead to a lower frequency of sufficient seasonal rainfall duration for agriculture, though how critical this is will depend on the location and crops.

4.6.3 Vulnerability of crop production to climate change

4.6.3.1 Methodology

Crop modelling was undertaken to determine the effect of climate change on maize and millet production around the middle of the century (the years 2046 to 2065).

In consultation with the MAWF and the GSA (Green Scheme Agency) BUDGET (V6.2, 2005) was selected as the software for running crop simulations, based on good experiences and existing expertise with the software. For input in the crop model, climate data was prepared by CSAG at the UCT for 4 downscaled GCMs (MRI, Miroc, HADCM and CSIRO), which were trained on historical data, comprising daily weather records for minimum and maximum temperatures, as well as precipitation for the period 2046 – 2065. Based on this dataset an average year for both the future scenario's and a reference or baseline scenario was developed which was fed into the crop model. Since Budget is a crop model that works with monthly data, daily input data were recalculated to mean monthly values for evapotranspiration and rainfall. This was carried out by means of minor data processing in DSSAT (Support System for Agrotechnology Transfer) and software called ETO which, using the Penman-Monteith methodology calculates evapotranspiration using inputs such as temperature, humidity, windspeed and radiation[6].

To run BUDGET site-specific soil profile data for both Rundu and Groofontein was used. These sites were selected considering their importance as major crop production sites *with* sufficient climatic and soil *data available* (these limitations are discussed in 'data issues and limitations' below), and the crop-specific data files for local varieties of both millet and maize. This information was obtained from the DART in the MAWF.

The modelling period for the average agricultural season started and ended 1st of August (encompassing a single southern hemisphere summer rainfall season). This period includes the onset (which is when a farmer can choose to plant and is here assumed to be the planting date) and the cessation of rainfall, which together measure the effective duration of the rainy season, and allows for the establishment of not only yields but planting windows as well.

4.6.3.2 Data issues and limitations

High demands both on climate data availability (30 continuous years of rainfall and temperature data is required to train the downscaled climate models for any given location) and high demands on person-days to calibrate the models and run the simulations limited efforts to Rundu and Grootfontein.

It has to be noted throughout that among the sources of uncertainty derived from the use of crop models for impact assessment are the following:

- Simple, empirically-derived relationships do not completely mimic actual plant relationships.
- Weeds, pests, and disease are assumed to be controlled.
- Not all future improvements in technology are included.
- There remain serious uncertainties about the effects of elevated CO2 on crop plants.

In addition the lack of climate data prevented the team to do crop modelling for the millet producing sandy soils in the North Central regions, although pursuing this option is highly desirable.

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[6] Radiation was based on longitude and latitude input data.

4.6.3.3 Impact of climate change on crop production: results

The crop simulations presented below give information for a reference scenario (the downscaled representation of the current climate), and for four downscaled GCMs on the start and end of the growing season and on expected yield levels for planting dates. Please note that all findings are indicative and care should be taken in the interpretation of any quantitative figures; in fact it is refrained from in the analysis of the results and solely trends are discussed, i.e. feasible planting windows and fundamental increases/ decreases in yield. This caution is based on discussions with both the CSAG and the MAWF which have extensive modelling experience and expertise between them.

4.6.3.3.1 Maize production - Rundu

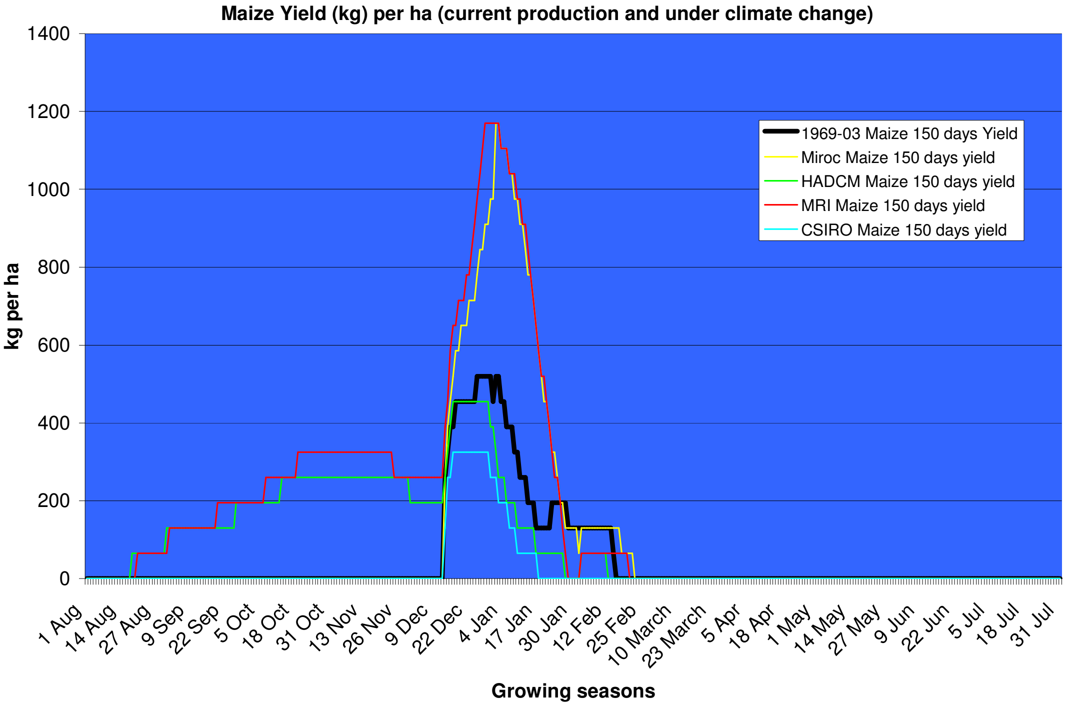


Figure 4.13: Modelled maize production in Rundu based on historic data and climate change predictions, applying BUDGET modelling software and 4 GCM climate models (Miroc, HADCM, MRI and CSIRO)

Planting windows

Under present climatic conditions, with the associated evapotranspiration levels and soil profiles predominant around Rundu, maize yields can be expected for a planting period roughly stretching from the second week of December to the latter parts of February (Figure 4.13). Should future climate evolve as predicted by the CSIRO data, future planting windows will be reduced considerably from the beginning of December to the latest into the 3rd week of January.

The MIROC model assumes a very similar planting window as the current weather would allow. Both MRI and HADCM models actually predict a significant increase in the planting window for the future, with some yields possible when planting as early as the middle of August in both scenarios. This result coincides with predictions by Hulme et al in 1996, as quoted in (Tarr 1999). Consistently all the crop models indicate the end of February as the absolute latest period in which maize can be planted in Rundu.

Potential Yield

MIROC and MRI both predict significant yield increases for future maize production in Rundu. Contrary, both HADCM and CSIRO indicate reduced yields for the future; CSIRO significantly more so (Figure 4.13).

4.6.3.3.2 Maize production – Grootfontein

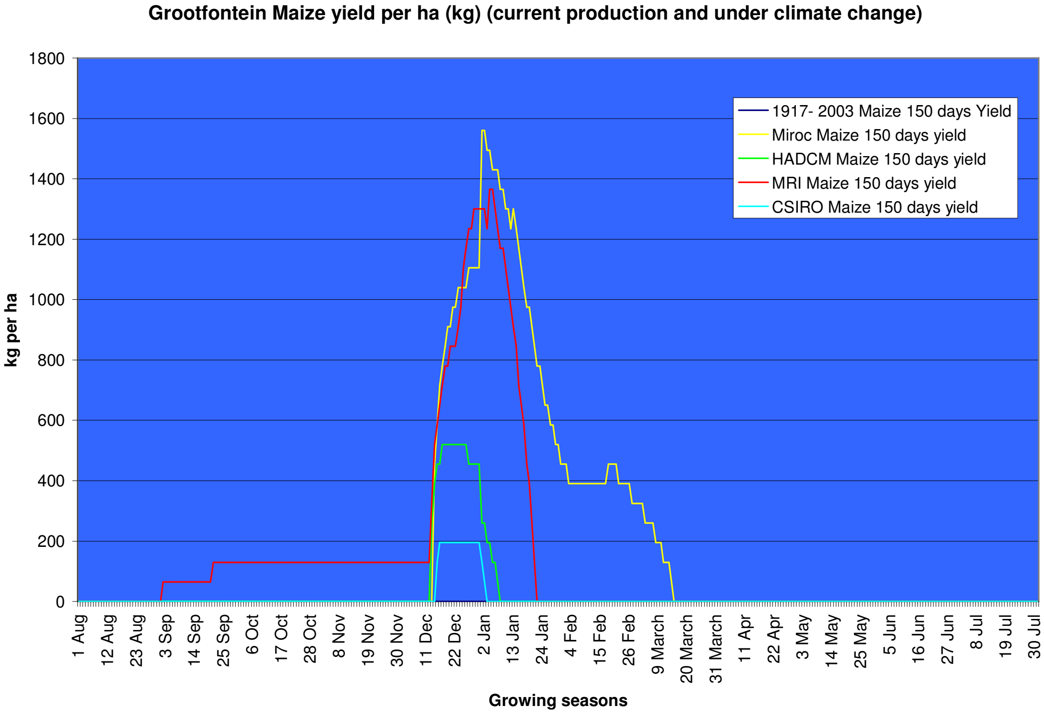


Figure 4.14: Modelled maize production in Grootfontein based on historic data and climate change predictions, applying BUDGET modelling software and 4 GCM climate models (Miroc, HADCM, MRI and CSIRO)

Planting windows

As far as projected/simulated maize production in Grootfontein in the period 2046-2065 is concerned, all simulations predict (their highest) yields when planting from early December to some time in January (Figure 4.14). The MRI model already allows minor yield when planting from early September, with a marked increase in yield planting around the second week of December and then a rapid decline when planting after the 10th of January. MIROC actually allows for much later planting, up to the first weeks of March.

Potential Yield

Note that BUDGET did not yield any maize crop under for the reference scenario based on climate data from 1917-2003. MRI and MIROC once more (as in the Rundu scenarios) promise the highest yield, whereas HADCM and again CSIRO, in particular, are much more conservative regarding future yields (Figure 4.14).

4.6.3.3.3 Discussion – maize production

No clear picture emerges from the maize crop modelling undertaken for Rundu (Figure 4.13). The MRI model promises improvements all-round; longer (earlier) planting windows and higher yields. CSIRO, on the other hand, is glummer on both accounts compared to current yields and planting window. Miroc follows the current period of a suitable planting period but promises huge gains in yields, whilst HADCM indicates a slight reduction in maximum yields but allows for a much longer planting window suggesting the possibility of earlier planting.

There are two striking features in the model results for Grootfontein (Figure 4.14): firstly, maize producers in the Grootfontein area should feel rather proud about managing any yields at all; BUDGET did not find a single suitable planting window under current climatic conditions. Secondly, all GCM simulations actually predict improved future maize yields, albeit marginal in the case of HADCAM and CSIRO. There appears to be consensus that the second week of December seems to be the earliest time of planting if relatively promising yields are to be obtained. Whilst HADCM and CSIRO indicate short planting windows around Christmas and New Year, MRI and especially MIROC predict scope for later planting in January and February for the future.

4.6.3.3.4 Pearl Millet production – Rundu

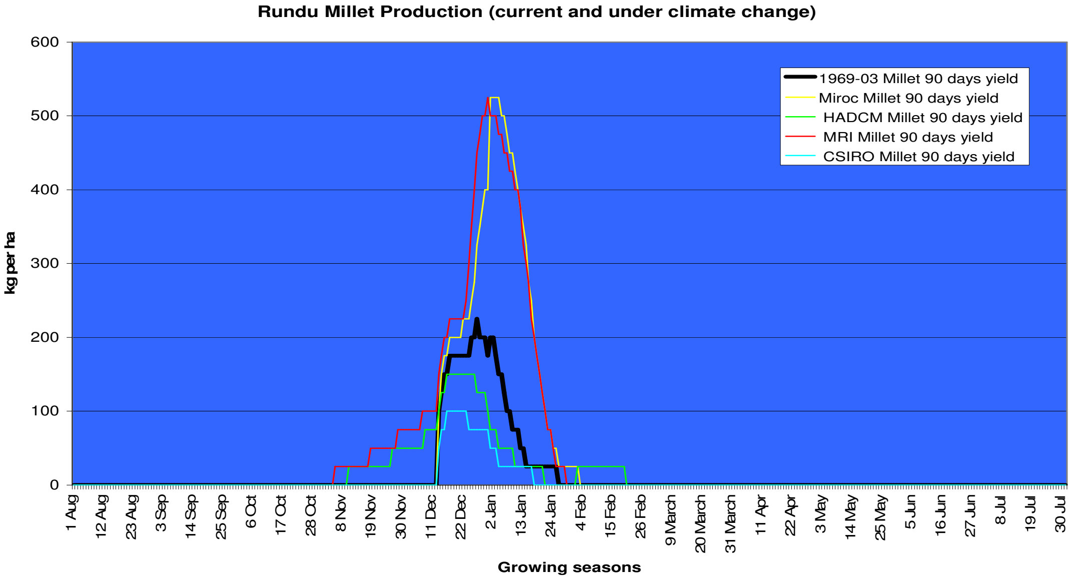


Figure 4.15: Modelled pearl millet production in Rundu based on historic data and climate change predictions, applying BUDGET modelling software and 4 GCM climate models (Miroc, HADCM, MRI and CSIRO)

Planting windows

The baseline scenario for Millet production in Rundu stretches from the second week in December to the second week of January. The CSIRO simulation in effect results in the same window, as does the Miroc simulation. Both MRI and HADCM predict a similar end to the season but allow incremental yields when planting from as early as the beginning of November.

Potential Yield

As observed for maize, the Miroc and MRI GCMs predict a weather pattern which will allow substantial increases in yield to be realized. Similarly, HADCM and CSIRO predict reductions in the yield potential; CSIRO again markedly more so.

4.6.3.3.5 Pearl Millet production – Grootfontein

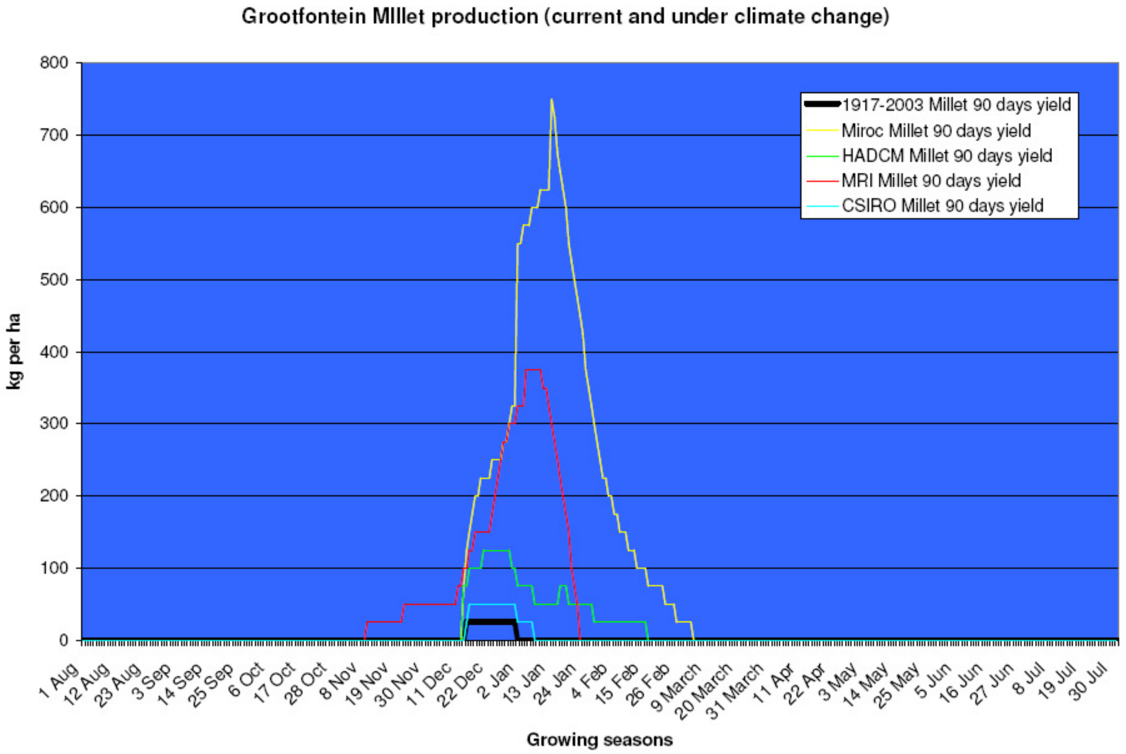


Figure 4.16: Modelled pearl millet production in Grootfontein based on historic data and climate change predictions, applying BUDGET modelling software and 4 GCM climate models (Miroc, HADCM, MRI and CSIRO)

Planting windows

All the GCMs suggest that in Grootfontein planting windows will enlarge, allowing good (and in cases optimum) yields to be obtained by planting outside the current planting window (which stretches from Christmas to the New Year). Both Miroc and MRI suggest the second week of January to the middle of February to be ideal for planting Millet in future. HADCM and CSIRO suggest slight increases in future.

Potential Yield

Similar to the production of Maize in the Grootfontein area farmers generate yields against all odds (according to the BUDGET modelling tool). Yet, all future models are predicting rather more optimistic yields when planting millet (possibly a few weeks later in the year), and again Miroc and MRI predicting substantially bigger yields around the middle of the century. These increases are very surprising.

4.6.3.3.6 Discussion – pearl millet production

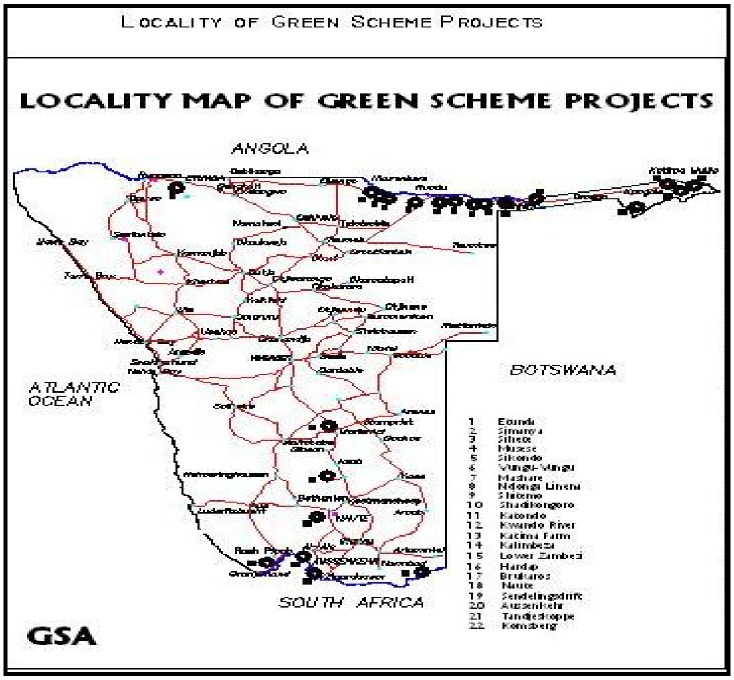
The results obtained for Rundu are unfortunately inconclusive as to the increase/decline in potential of producing pearl millet in the area around the middle of the century. What remains is *a* potential to continue producing Millet in the region, and planting windows are likely to remain stable or, on a positive note, become slightly larger.

In the case of Grootfontein the modelling of millet production yields a surprise; later planting, rather than earlier planting as suggested in all other models and the literature (at least on Maize (Tarr 1999), seems to yield better results. Consistently with other simulations Miroc and MRI show great potential increases in yield in the future, although the uncertainties in particular with the interpretation of these increases have to be stressed.

4.6.3.4 The Green Scheme and climate change

The Green Scheme (GS) aims to encourage the development of agronomic production and enhance contribution of agriculture to GDP, stimulate private sector investment, combat poverty and achieve social development of communities within suitable irrigation areas. The GS will create opportunities for the settlement of small scale irrigation farmers (SSIF), and envisages cooperation between commercial irrigation farming enterprises (CIFE) and SSIF's.

Figure 4.17: Locality of Green Scheme Projects in Namibia



The aim is to add some 27 000 ha of irrigated land to the current areas covering ~ 10 000 ha in total. The current schemes consume ~ 160 Mm³, which amounts to about half of the nations average total water demand. (Republic of Namibia 2006e) It is envisaged that about 33% of the extended area will be put under vegetable production; ~ 9000 ha requiring ~ 110 Mm³ per year. The larger area, 18 000 ha, is likely to by put under grains requiring ~ 180 Mm³ per year (personal communication, Prinsloo 2008).

22 000 ha (81%) of the new proposed schemes lies west along the Kavango river, with the remainder spread throughout the country (see Figure 4.17). Chapter 3 highlights that future drainage, even with an assumed drop of 10% in precipitation only, areas with annual rainfall of 500 – 800 mm (as is the case of the proposed GS sites), may loose 60% to 30% respectively of perennial drainage (see the yellow zones in Figure 3.3 a and c on page 51).

The schemes are based on 5% abstraction of river flows, but the potential loss in drainage might affect the viability of the scheme.

Whereas irrigation schemes have the great advantage of militating against dry / drying of certain areas, crop yields in these schemes is also influenced by temperature and other variables. Warmer winters, as predicted for Namibia, broaden the spectrum of potential winter crops, whilst the occurrence of plant diseases under irrigation with possibly higher humidity is more severe. Increased temperatures will certainly increase water demand; what will happen to yields is not so clear as water supply, temperature and CO2 create trade-offs as discussed in other parts of the chapter.

Improving water use efficiency as part of intensified farming systems such as with tunnels or with hydroponics allows a virtual de-coupling from rain events. Yet, in order to practice these farming systems vast amounts of funds have to be spent not only on infrastructure but also on training of farmers, as management expertise needs to be strengthened significantly.

The opportunity of feedlots in areas where irrigation intensifies is large, with synergies between the feedstock and the manure to be exploited. In light of the stress the Namibian livestock industry is likely to be exposed to due to climate change these synergies might become invaluable, although they again present a major shift in farming system with the heightened requirements for capital and management skills.

4.7 Vulnerability of livestock production to climate change

4.7.1 Introduction

No modelling of the impact of climate change on livestock production in Namibia was undertaken due to a lack of capacity for this type of impact modelling. Nonetheless, based on literature review and stakeholder consultation some light is shed on what the expected impact will be. The discussion will focus on the following factors which have been identified as most crucial:

- Grazing availability, quality, and bush encroachment
- Livestock production and reproduction
- Water availability and demand
- Disease and parasite impact

4.7.2 Grazing availability, quality and bush encroachment

4.7.2.1 Introduction

Grazing ecosystems are affected by alterations in precipitation regimes, temperature, and atmospheric concentrations of CO_2; the effects are played out in, amongst others:

- changes in aboveground net primary production (NPP)
- shifts in C3/C4 species of grasslands,
- changes in evapotranspiration and runoff; and
- changes in forage quality

(Rosina M. Bierbaum and (eds.) 2007)

The indirect effects are less well understood. Because of lags in the response time of the system and the complexity of the feedbacks that are involved, the impacts of climate change take longer to identify. Also human activities, including burning, cropping, and management of grazing animals, have the potential to modify indirect effects by either accelerating or slowing these processes. Indeed, these factors have been found to be at the very heart of land and pasture degradation in the literature (Herrmanna 2005).

Namibia is characterized by major seasonal changes in both composition and quantity of grazing (Jenny Bester 2001). Balancing stocking rates with herbage production is particularly difficult in arid and semi-arid areas where there is considerable variability in rainfall will remain the most pressing challenge, only exacerbated by the slow-onset climate change (Watkinson and Ormerod 2001). Changes in the level of market integration of pastoralists, changes in customary law and tenure systems related to the practice of transhumance in many parts of Namibia, and many other factors have forced expansion of grazing into areas of even greater marginal productivity, which places extreme pressures on an already stressed ecosystem. This is acknowledged as traditional pastoralist systems that are seen in many regions of the developing world are less likely to have the flexibility built into the system for adapting to extreme climatic events (such as changing the type or mix of grazing livestock, cross-breeding, relocating). Sections of Namibian society practicing transhumance see their traditional practices of dealing with uncertainty seriously undermined.

Changes in climate are likely to produce alterations in the boundaries between rangelands and other biomes, such as deserts and forests, directly through shifts in species composition and indirectly through changes in wildfire regimes, opportunistic cultivation, or agricultural release of the less arid margins of the rangeland territory. Many of these effects are already affecting rural Namibia, with grazing conflicts, ever-spreading desertification and huge variability in production figures frequently reported on in the media.

4.7.2.2 Rangelands and climate change - Namibia

(Midgley et al. 2005) states that “significant changes in vegetation structure and function are projected in several areas of Namibia by 2080”. The dominant vegetation type simulated in Namibia under current climate conditions, termed Grassy Savanna, is projected to lose its spatial dominance to Desert and Arid Shrubland vegetation types.

The “Assessment of potential climate change impacts on Namibia’s floristic diversity, ecosystem structure and function” is the most comprehensive report of its nature in the southern hemisphere (Midgley et al. 2005) and held in high regard by experts in this field. The uncertainty which occurs throughout the literature on climate change and its impact remains however, as the authors immediately state that “the impacts of rising atmospheric CO_2 that may directly increase plant primary productivity and therefore ameliorate vegetation response to climate change, introduce substantial uncertainty in projections in some parts of the country, mainly in the savanna woodland ecosystems of the northern Kalahari and northeastern Kalahari woodland regions”. Figure 1 and 2 below clearly indicate the competition from C3 plants over the next decades in the north-eastern parts of the country, resulting in high levels of bush encroachment (especially in the scenario which incorporates the CO_2 effect). The graphs indicate a retreat in C4 grass-cover over time in a north-easterly direction; this reduction in cover is much more dramatic in the 2080 Scenario with the CO_2 effect (relevant part within Figure 9 highlighted by the frame) so conducive for the thriving woody C3 species in the northeastern part of Namibia (as in the framed part in Figure 10).

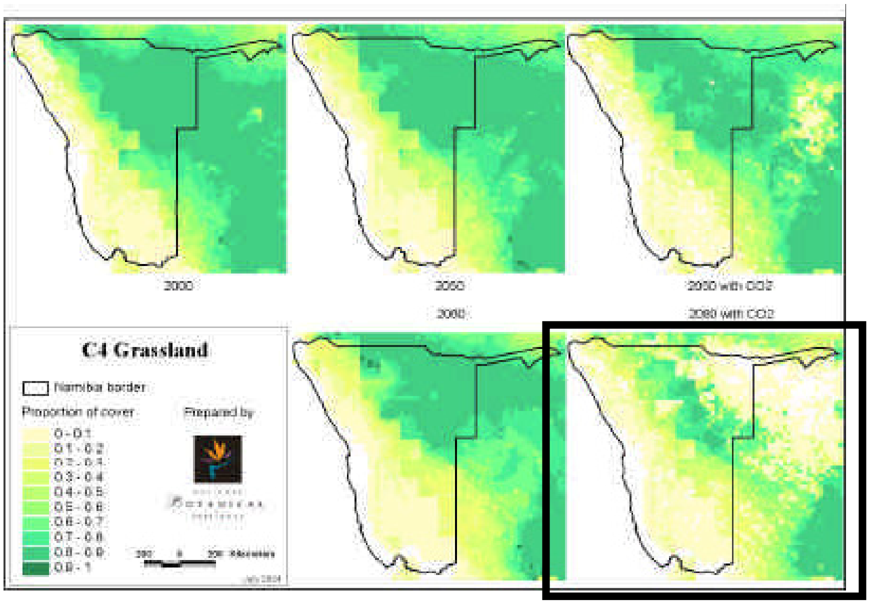


Figure 4.18: C4 Grassland cover in 2000, 2050 and 2080 (with and without CO2) (Midgley et al. 2005)

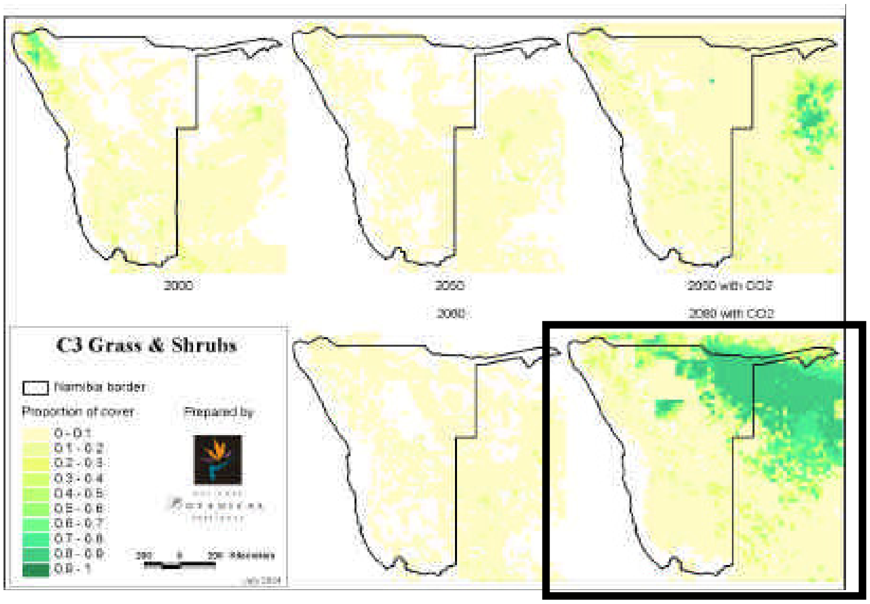


Figure 4.19: C3 Grass and shrub cover in 2000, 2050 and 2080 (with and without CO2) (Midgley et al. 2005)

The impact of climate change on rangelands is likely to vary between geographic and agro-ecological systems because of the expected differences in the nature of climate change between regions. It has been established that vegetation greenness in semi-arid environments is more strongly related to soil moisture, a function of rainfall accumulated over a period of time, than to instantaneous rainfall (Herrmanna 2005).

4.7.2.3 CO_2 fertilisation

The literature review of climate change and impacts on rangeland inevitably comes back to one topic: CO_2 fertilisation. As such a special mention of this factor is made.

Experimental evidence from a number of studies indicates that elevated concentrations of atmospheric CO_2 increase the rate of photosynthetic carbon assimilation in plants. This effect, frequently referred to as CO_2 fertilisation, has been found to apply to both C3 plants (e.g. trees, forbs and temperate grasses) and C4 plants (e.g. tropical grasses), although responses vary between species and tend to be smaller in C4 species (Harle 2007). Elevated CO_2 has also been demonstrated to decrease stomatal conductance and leaf transpiration, thus increasing the water use efficiency of plants and in turn the effective soil water content. This increase in efficiency in the conversion of water into dry mass has been shown to raise above ground and, in some cases, below ground plant productivity.

In water-limited conditions, such as experienced in virtually all of Namibian rangelands, the main benefit of increased levels of CO_2 is derived through the interaction of plant water use efficiency and soil moisture. It has been projected that the combination of these effects under enhanced CO_2 conditions will improve the ability of plants to withstand the stresses associated with reduced rainfall, although this will vary with species and soil conditions. In terms of pasture growth, it has been suggested (Harle 2007) that under elevated CO_2, the moisture- CO_2 interactions may buffer the effects of inter-annual variation in rainfall on grass production. Plant growth response to elevated CO_2 is dependent on other variables such as temperature, rainfall, soil moisture and soil nutrient availability - especially nitrogen. Another important factor is forage quality; it is suggested that warming would significantly decrease the non-structural carbohydrate concentrations and digestibility of rangelands, and that elevated CO_2 concentrations coupled with warming may exacerbate nutrient deficiencies in those systems which are already deficient in nitrogen (Harle 2007).

There seem to be some biophysical limits though, one or two of which is of particular relevance to Namibia: Where water availability is particularly limiting, such as our arid to semi-arid ecosystems, the effects of CO_2 on soil water dynamics may not be detectable. Indeed, studies suggest that beyond a threshold of between 300 and 500 mm precipitation/year further decreases in precipitation can offset the positive effects of enhanced CO_2 conditions on plant growth. Similarly, low nutrient availability can limit the response of plant productivity to raised CO_2. There is also some indication that nitrogen availability can become increasingly limited through time, with nitrogen being sequestered in greater amounts where there is increased biomass as a result of elevated CO_2 (Harle 2007).

4.7.2.4 CO_2 fertilisation and bush encroachment

The direct impact of elevated CO_2 on Namibian ecosystems requires further investigation. Future change with CO_2 fertilization suggests a weak CO_2 impact in the arid coastal belt central escarpment and southern central regions. However, significant CO_2 fertilization appears to permit expansion of novel woody C3 vegetation types in the north-east regions of the country (Midgley et al. 2005). This is almost certainly due to a CO_2 stimulation of woody C3 shrubs in regions where sufficient moisture is available to support an appreciable leaf area index, and there is an increase in soil nitrogen availability due to ecosystem feedbacks. On the topic of bush encroachment evidence suggests that elevated CO_2 may affect not only individual plant species but also community composition through avenues such as differentially affecting the survival, vegetative growth, seed production and seedling recruitment of some species.

Bush encroachment is detrimental to Namibia's livestock industry with losses amounting to N$ 700 Million per annum (de Klerk 2004). Bush encroachment has a direct impact on the livelihoods of both communal and commercial farmers and their employees, and amongst other factors, is responsible for reducing the commercial herd of livestock in Namibia from 2.5 million in 1958 to some 800,000 in 2001 according to the Meatboard of Namibia, as well as reducing job opportunities in the rural agricultural sector. Carrying capacity in infested areas is reduced to half or even less of its original value.

In conclusion to this section on rangelands the main findings of the (Midgley et al. 2005) report are reiterated:

- Arid vegetation types increase in cover by almost 20% by 2050, and up to 43% by 2080 in the absence of a CO_2 fertilization effect
- Vegetation is projected to suffer some reductions in cover and reduced Net Primary Productivity (NPP) throughout much of the country by 2050 (exacerbated by 2080), with important implications for the faunal component of Namibia's ecosystems, and the agricultural sector which relies for the majority on extensive grazing regimes.

This assessment is shared at the global level where large parts of Namibia are classified as ecologically highly vulnerable to future climate change, as the figure below indicates.

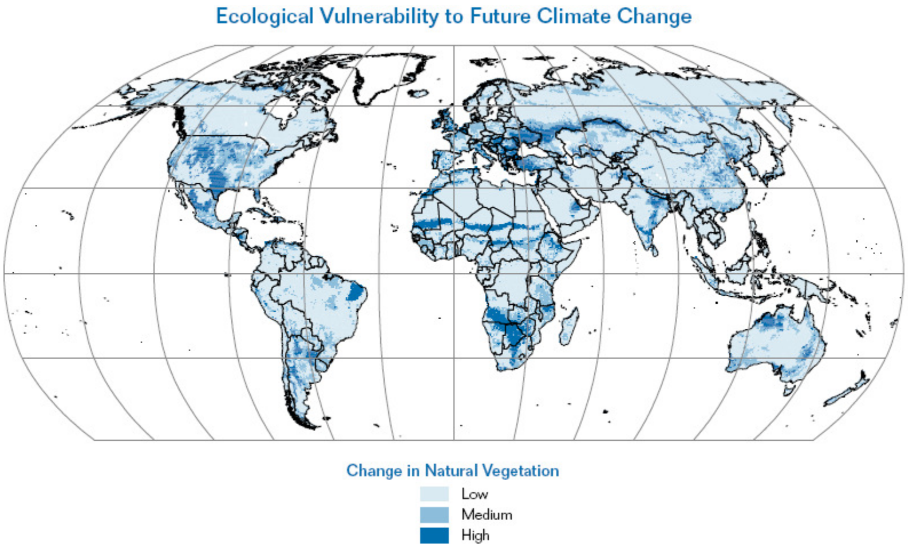


Figure 4.20: Ecological Vulnerability to CC (Rosina M. Bierbaum and (eds.) 2007)

4.7.3 Livestock production and reproduction

The well-being and productivity of livestock in natural conditions depend on the animal's ability to cope with environmental challenges such as nutritional and thermal changes and exposure to disease and parasites. The direct effects from heat and water stress on grazing or browsing livestock are most likely to be manifested as decreases in feed intake, milk production, and rates of reproduction. The indirect effects of climate driven changes on animal performance result from alteration in the animal's nutritional environment (Feenstra et al. 1998).

4.7.3.1 Heat stress and tolerance

Chapter 1 discusses the modelled mid-century climate in detail, and the section on temperatures is of particular relevance for this section. In summary, it is expected that both during winter and summer both minimum and maximum temperatures are to increases markedly, resulting in increased levels of heat stress.

Heat stress in animals reduces their appetite and consequently their food intake. This may lead to a reduction in milk yield, reproductive efficiency, and increased embryo mortality in the cow and ewe. The lamb and beef calf will grow at a slower rate if stressed. There are few detailed experimental studies of the effects of periods and degrees of heat stress. One study however revealed that in which animals were exposed to high levels of stress for several hours per day, show reductions in intake of up to 15% (Howden and Turnpenny 1998). The metabolic energy available for growth is consequently reduced for the beef calf and lamb. For the ewe and cow the situation is slightly more complicated as the animal may be using energy for pregnancy or lactation, as well as maintenance and growth.

The loss in metabolic energy is in theory experienced in the following order:

- the energy for lactation is reduced;
- the energy for growth is reduced;
- the energy for pregnancy is reduced; and
- the animal loses weight (D. J. Parsons 2001)

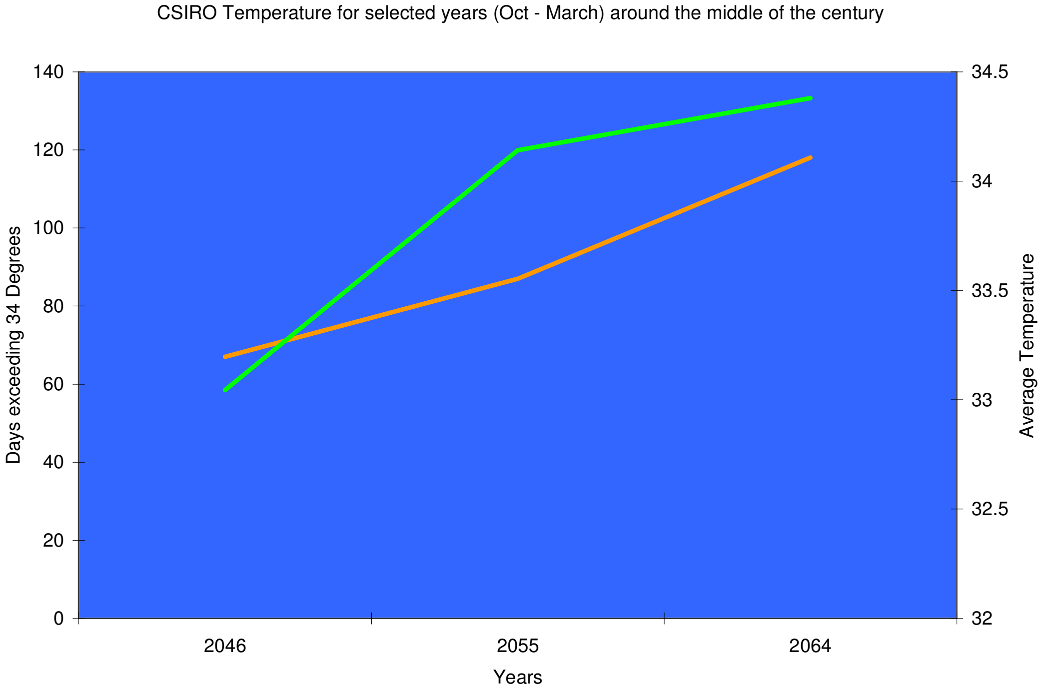
There appears to be strong compensatory growth responses when animals are returned to less stressful (heat-stress related) conditions (Howden and Turnpenny 1998). Young animals seem to deal much better with heat stress than mother stock (D. J. Parsons 2001).

Animals do have considerable resilience for maintaining normal functions, particularly growth, through adaptive and compensatory capabilities. Energy utilization and resultant productive performance measures are described by continuous rather than discontinuous functions when related to ambient temperature (Hahn 1994). Yet, there are limits to the heat-stress animals endure and certain thresholds have been established. High rectal temperatures of 40°C in European breeds are observed in cows at about 33- 34°C ambient temperature, whereas 40°C rectal temperatures in Sanga types at 39 - 40°C ambient temperatures have been reported. Negative correlations between pregnancy rate and rectal temperatures in cows have been proven (Swanepoel and Setshwaelo 1995). These results have implications on cow breed types- and reproductive management in Namibia.

In the cattle-producing states of the USA the weather service issues special forecasts during extremely hot weather to alert livestock producers of dangerous weather. The warnings are based on a temperature-humidity index (THI), which increases as the temperature and humidity increase. The danger level is indicated by an index value of 79, which is reached in various combinations of temperatures above 29 Degree Celsius in combination with high humidity. As temperatures increase, slightly lower humidity can still create dangerous and emergency conditions. The emergency levels begin at an index level of 84 and occur at temperatures in 32°C and 37°C range, increasing in danger as the humidity level increases.

To test these figures against the limited information available in Namibia, a sample for the 6 warmest months in 2046, 2056 and 2064 (Figure 4.21) was taken (the CSIRO data generated for the crop modelling in Rundu was used), and the change in average maximum temperature as well as the frequency of days exceeding 34°C, measured.

Figure 4.21: Increase in average temperatures and occurrence of days above 34 Degrees Celsius for heat months in 2046, 2055 and 2064



The results are rather disconcerting, in less than 20 years around the middle of the century days exceeding 34°C will move from 67 to 118 days (out of 180 days). Average maximum temperatures are predicted to increase by more than one Degree Celsius in that period, from 33.04°C to 34.38°C exceeding the official thresholds for European breeds getting pregnant.

Temperature is the most important climatic factor affecting the performance of animals. The comfort zone for Indian breeds lies between 10°C and 26,7°C. (Yao 1975) Comparing the Brahman, for example, with European cattle a University of Missouri study found that Brahman and European cattle thrive equally well at temperatures up to 21°C, above this value European cattle decline in appetite and milk production. Brahman cattle however, showed little effect of temperatures up to 38°C. A factor which contributes to this ability to withstand temperature extremes is a short, thick, glossy hair coat which reflects much of the sun's rays, allowing them to graze in midday sun without suffering. An abundance of loose skin, characteristic of the breed, also aids in its ability to withstand warm weather by increasing the body surface area exposed to cooling. In cold weather the skin is contracted, increasing the thickness of the hide and density of the hair, which aids in retaining body heat. A special feature of the Brahman breed is their ability over other breeds to sweat freely, which contributes greatly to their heat tolerance.

The Sanga's, such as the Nguni breed, shows that it developed under a process of natural selection in a highly challenging environment. It is a medium-frame animal with a measure of tick tolerance and disease resistance (Jenny Bester 2001). Smaller animals require lower amounts of maintenance, which is more easily met by the available rangelands. As a selective grazer and browser, the Nguni appears to obtain optimal nutritional value from the available natural vegetation, thus enabling it to survive under conditions that bulk grazers such as the European cattle breeds find extremely testing. The Nguni also has adaptive traits such as excellent walking ability, which enables it to walk long distances in search of grazing and water. It is also reported to be tolerant of extreme temperatures (Jenny Bester 2001). (Swanepoel and Setshwaelo 1995) has attributed this to breed size (mature size) and body weight; the rate of heat dissipation per unit weight has been found to decrease with increase in temperature. This implies that at high ambient temperatures, larger breeds would accumulate in their body more total heat (core body temperature) resulting in higher rectal temperatures than in smaller breeds. Body conformation, coat type and color, skin thickness and pigmentation, and metabolic rates (and associated heat of production) have also been attributed to heat tolerance of Sanga breeds.

Dairy cattle, though not large in numbers in Namibia, are nonetheless of socio-economic importance as, on the one side the commercial operations (contributing 3,1% to the agricultural sectors share in the GDP, 2004 figure) enjoy industry infant-protection status and consumers therefore subsidize the industry, and on the other hand milk production plays a crucial role in household food security in most of Namibia’s communal areas.

The following physiological effects are generally observable in heat-stressed dairy cattle (Jones and Hennessy 2000):

- Cows seek shade (which reduces grazing time, when stress periods are prolonged)
- Reduced food intake
- Weight loss
- Open mouths and laboured breathing
- Decreased reproduction rate
- Increased somatic cell counts and risk of clinical mastitis
- Increased body temperature and respiration rate
- Inability to move
- Collapse, convulsions, coma, death

The following production effects are discernible:

- The cows with highest milk yield are the first to show heat stress symptoms
- Cows with no shade producing above 20 L/day experience stress when THI exceeds a value of 72. Mild stress occurs for a THI of 72 to 78, leading to decreased milk yield, milk fat content and protein content.
- For cows with no shade producing above 20 L/day, significant stress occurs for a THI of more than 78, and milk yield declines markedly

Unfortunately, THIs are not calculated for Namibia but these thresholds are markedly lower than for beef cattle (where a THI of 79 signifies ~ 29 Degrees Celsius), and the viability of this industry/ farming system is therefore seriously in doubt if adaptation measures are not implemented.

4.7.3.2 Focus on sheep and goats

Smallstock plays an important role in all parts of Namibia. In the southern regions, due to its aridity, smallstock is the most important farming system. In the Karas region sheep outnumber cattle by a factor 30, with an additional 235,000 goats (of which 98% are boergoats). 76% of the sheep are Dorpers, and 11% are Karakul. Other sheep breeds make up 13% of the total.

Changes to pasture availability and quality may also affect the reproduction of sheep. For example, reduced nutrition in the last 6 weeks of pregnancy, such as caused by a lack of green herbage under drought conditions, can result in an increased incidence of pregnancy toxaemia, particularly in ewes bearing twin lambs. Changes in feed supply can also affect ewe weights and in turn ovulation rates and reproductive performance (D. J. Parsons 2001).

Heat stress is not considered to directly affect oestrous activity in sheep, although an indirect effect may arise through nutritional stress due to limiting time spent grazing, and through poorer quality pastures (as discussed in the rangelands section earlier in the chapter). There is the potential for such indirect effects on oestrous to be negated through the use of supplements, although such use will be governed by questions of cost effectiveness of application.

Studies of the reproductive physiology of sheep indicate that heat stress is a major factor in lowering reproductive performance. Heat stress can reduce ram fertility (which is linked to increased failure of fertilisation due to defective gametes) and increased neo-natal mortality in lambs. Sheep that are poorly adapted to heat stress suffer increased levels of embryonic mortality and reduced foetal growth when exposed to continuously hot conditions (D. J. Parsons 2001). Mortality in lambs produced by ewes experiencing heat stress is higher than in lambs produced during cooler conditions (Harle 2007).

Increases in thermal stress not only reduced animal productivity through lower growth rates due to appetite suppression and decreased reproductive rates but also increases concerns about animal welfare in intensive livestock handling activities, such as live sheep exports.

In contrast, higher minimum temperatures may result in reduction in the frequency and severity of cold-stress events, such as conditions that foster high lamb mortality and post-shearing losses.

4.7.4 Water demand

Climate change is likely to affect water resources by increasing the demand for water, changing surface water and streamflow regimes (e.g. flooding as experienced at times in the Karas region), and through possible effects on groundwater, such as depth to the water table and water quality. The section on groundwater recharge in Chapter 3 concludes that scientists agree that a decline in groundwater recharge and resources would be expected over the semi-arid and arid regions of Southern Africa under currently accepted climate change scenarios. Such general indications are based on straightforward rainfall – recharge relationships, and as such implications of climate change for groundwater are uncertain and are likely to vary markedly from place to place, depending on the rate of subsurface flows, the nature of the re-charge zone and the nature of the climate change).

Water demand by livestock is strongly related to temperature and is therefore likely to increase as temperatures rise in the future (one study in Australia suggested that a temperature rise of 2,7 Degrees Celsius results in around 13% increase in water demand (Howden and Turnpenny 1998). Lack of availability of water due to the large distances from water sources that Namibian animals sometimes have to forage, can reduce production directly through reductions in metabolic rates and feed intake and indirectly by reducing the area grazed through restriction of distance traveled from watering points (Howden and Turnpenny 1998). The cost of water supply on Namibian farms is already high, and a decline in groundwater tables will not only result in higher fixed costs for drilling, but increase the costs of pumping.

Higher water use rates by livestock and the inability to forage as far from watering points, is limiting use of resources in extensive grazing operations and tending to increase grazing pressure near watering points. This in turn could contribute to land degradation in the sheep producing regions. There is a strong possibility that climate change will exacerbate a number of types of land degradation. For example, where rainfall is significantly reduced plant cover is negatively affected and grazing lands become more susceptible to soil erosion. This process serves to reduce pasture productivity through loss of valuable soil nutrients. Erosion may also be an issue with the suggested increases in extreme daily rainfall events, particularly in Namibia where reductions in annual rainfall amounts have negatively impacted on vegetation cover.

Recharge of farm dams, as small reservoirs, could be negatively affected by climate change in areas where lower precipitation is predicted. Higher temperatures and lower flows may also increase blue-green algae blooms and also potentially increase salt concentrations in water (D. J. Parsons 2001). The latter would in turn raise the water requirements of stock. In contrast, the potential increases in rainfall intensity as predicted for the northern parts of the country, could raise the chance of flood conditions, which would also increase the chance for runoff conditions to fill on-farm water storages.

4.7.5 Disease and parasite impact

Many important animal diseases are affected directly or indirectly by weather and climate. Climate can affect distribution of a disease as well as the timing of an outbreak or the intensity of it. Many animal diseases of significant impact in Namibia are influenced by climate. Such influences are not the sole preserve of vector-borne diseases; certain directly transmitted food/waterborne and aerosol transmitted diseases are also affected. A common feature of non-vector-borne diseases affected by climate is that the pathogen or parasite spends a period of time outside the host, subject to environmental influence.

Climate appears to be more frequently associated with the seasonal occurrence of non–vector borne diseases than their spatial distribution.

4.7.5.1 Effects of climate change on pathogens

Higher temperatures resulting from climate change may increase the rate of development of certain pathogens or parasites that have one or more life cycle stages outside their animal host. This may shorten generation times and possibly increase the total number of generation per year, leading to higher pathogens/parasite population sizes (Harvell et al. 2002)

It is for example the infective spores of Anthrax and blackleg, and the moisture-dependent survival of the agents of Dermatophilosis (a fungus), or Haemonchosis (worms), that may be affected. In contrast, diseases transmitted directly between animals in close contact have few reported associations with climate, e.g. Avian Influenza, Bovine tuberculosis, Brucellosis, Contagious bovine peri pneumonia (CBPP), Foot-and-mouth disease (FMD), Newcastle's disease, Coccidiosis, Rabies, bovine viral diarrhea (BVD) (Hager 2007).

4.7.5.2 Effects of climate on hosts

Mammalian cellular immunity can be suppressed following heightened exposure to UV-B radiation, an expected outcome of stratospheric ozone depletion (Aucamp 2003). In particular there is depression of the number of T helper 1 lymphocyes involved in the immune response to intracellular pathogens. Such pathogens include viruses, rickettsia (like Cowdria which causes heartwater present for the moment only in Caprivi, and Anaplasma which occurs throughout Namibia) and some bacteria such as Brucella. Furthermore, increased UV-B exposure may diminish the host's response to certain vaccinations (De Gruijl et al. 2003).

A second host-related effect is genetic resistance to disease. Many animals have evolved a level of genetic resistance to some of the diseases to which they are commonly exposed. It seems unlikely that climate change will directly affect genetic or immunologic resistance to disease in livestock. But with significant shifts in disease distributions driven by climate change, naïve populations may, in some cases, be particularly susceptible to the new diseases facing them. To explain this further certain diseases show a phenomenon called endemic stability which occurs when the disease is less severe in younger than older animals, when the infection is common or endemic and when there is lifelong immunity after infection. Under these conditions most infected individuals are young, and experience relatively mild disease. Certain tick-borne diseases, such as anaplasmosis, babesiosis and cowdriosis, show a degree of endemic stability (Eisler et al. 2003). If climate change drives such diseases to new-areas, non-immune individuals of all ages in these regions will be newly exposed, and outbreaks of severe diseases could follow.

4.7.5.3 Effects on vectors

There are several processes by which climate change might affect disease vectors. First, temperature and moisture frequently impose limits on their distribution. In a scenario where there is increased precipitation or humidity, Namibia will become more permissive for vectors. It is likely to become more conducive to vectors as it is becoming warmer and for most parts the moisture level will increase. As well, greater intra-or inter-annual variation in rain fall may lead to an increase in the frequency or scale of outbreaks of such diseases.

There may be important effects of climate change on vector dispersal, particularly if there is a change in wind patterns. Wind movement has been associated with the spread of epidemics of many Culicoides-and mosquito-borne diseases (Sellers et al. 1982).

In addition, climate change may be one of the forces that lead to changes in future patterns of international trade, local animal transportation and farm size, all of which may affect the chances of an infected animal coming into contact with a susceptible one. For example, a series of droughts in east Africa between 1993 and 1997 resulted in pastoral communities moving their cattle to graze in areas normally reserved for wildlife. This resulted in cattle affected with a mild lineage of rinderpest transmitting the disease both to other cattle and to susceptible wildlife, causing severe disease, for example, in buffalo, lesser kudu and impala, and devastating certain populations (Kock et al. 1999).

4.7.5.4 Other indirect effects

Climate change may affect the abundance or distribution of hosts or the competitors/ predators/ parasites of vectors and influence patterns of disease in ways that cannot be predicted from the direct effects of climate change alone. Equally, it has been argued that climate change-related disturbances of ecological relationships, driven perhaps by agricultural changes, deforestation, construction of dams and loss of biodiversity, could give rise to new mixtures of different species, thereby exposing hosts to novel pathogens and vectors and causing the emergence of new diseases (WHO 1996).

4.8 Implications for agricultural production in Namibia

4.8.1 Climate data and (crop) modelling

There is a discontinuity in climate information available to inform adaptation and vulnerability assessments in the present (using observed climate), and that which can be used for the far future (GCM or downscaled projections). This study was informed by good quality data, but not many stations (i.e. not one such for the North Central Area) have the required lengths or completeness of data required for training the downscaled models and subsequently neither for crop modelling. In addition, crop models have their own shortcomings, as discussed in section 4.6.3.2.

Correlations between the observed trends in climate data, related to maize production, and the predictions from the modelling could not really be found, e.g. findings in the projected planting windows contradict to a large extent the observed trends as in Figure 4.10-4.12. Divergent from the simulations, the current trend indicates a late onset of the rain and thus later starts of the planting windows for Rundu, with flexibility towards the latter part of the rainy season (later cessation) observed in the trend.

Similarly the projected extended planting windows into March for millet production in Grootfontein are in conflict with the observed trend, which indicates earlier cessation according to Figure 4.11. It should be noted though that in these cases none of the trends observed were statistically significant.

In the simulations Rundu yielded inconclusive results throughout; simulations both on maize and millet for Grootfontein promise better cropping conditions around the middle of the century.

The results from the crop modelling clearly demonstrate that the many uncertainties and subsequent gaps in the models (e.g. uncertainties include the GCMs per se, their downscaling, the heterogenous response to climate at the plot level, uncertainties about management capacities of land users). Major gaps prevail in developing a better understanding of what really is likely to happen to the crop sector under climate change. This conclusion is also echoed by Hulme (1996) stressing careful examination of the effects of climate change on plant growth. Yield quality might also be negatively affected concomitantly with shorter growing seasons as Nitrogen levels in the grains are reduced (Hulme 1996).

The brief section on the Green Scheme highlights the potential of irrigation, but also the biophysical limitations which might be relevant.

4.8.2 Livestock sector

Namibia is characterized by major seasonal changes in both composition and quantity of grazing. Climate change is likely to result in a forced expansion of grazing activity into areas of even greater marginal productivity, which places extreme pressures on an already stressed ecosystem. To make matters worse it has been projected that significant changes in vegetation structure and function are projected in several areas of Namibia due to climate change; the dominant vegetation type termed Grassy Savanna is projected to lose its spatial dominance to Desert and Arid Shrubland vegetation types. Vegetation is projected to suffer some reduction in cover and reduced Net Primary Productivity (NPP) throughout much of the country.

A sample of the projected climate data for Namibia indicates that in less than 20 years around the middle of the century days exceeding 34 °C will move from 67 to 118 days (out of 180 days). Average maximum temperatures are predicted to increase by more than one Degree Celsius in that period, from 33.04 °C to 34.38 °C, which is above the threshold for some of the popular breeds in Namibia. Indigenous livestock, being smaller animals, require lower amounts of maintenance, which is more easily met by the available rangelands. Dairy cattle, on the other hand, seem to face even more severe pressure in extensive systems in Namibia. Heat stress in sheep is reported to result in changes in ovulation rates, reduced ram fertility, pregnancy toxemia (ewes dying) and neo-natal lamb mortality, and fewer lambs being born. Welfare issues in intensive industries as live sheep exports also become a concern when average temperatures increase.

Water demand by livestock is strongly related to temperature and is therefore likely to increase as temperatures rise in the future. Other factors, such as evaporation from dams also come into play. Lack of availability of water due to the large distances from water sources which Namibian animals sometimes have to forage, can limit production directly through reductions in metabolic rates and feed intake and indirectly by reducing the area grazed through restriction of distance traveled from watering points.

Erosion may also be an issue with the suggested increases in extreme daily rainfall events.

Warming and changes in rainfall distribution in Namibia will lead to changes in the spatial or temporal distributions of those diseases sensitive to moisture such as Anthrax, Blackleg, Dermatophilosis, Haemorrhagic Septicaemia, Haemonchosis and some vector-borne diseases.

4.8.3 Discussion

Farming in an arid country such as Namibia is a challenge at the best of times, and even more so if the sector is to contribute directly to the GDP and not only act as a social safety net. Highly industrialized parts of the world (countries such as Israel and states such as California) have demonstrated marked successes dealing with factors such as heat and limited rainfall; yet resource poor farmers and economies which depend for the most part on primary resources, such as Namibia, will find it difficult to emulate these advances in the short run. Already funding for the Green Scheme poses a major bottleneck in the implementation of the Scheme.

Whilst admitted uncertainties regarding the Namibian future crop production potential prevail[7], it seems fair to say that the stresses on the livestock sector will increase, particularly for small-scale farmers facing a lack of capital and skills to implement adaptation measures.

It appears as if the physiological thresholds for exotic beef cattle in Namibia is fast approaching, and due consideration can be given to the promotion of indigenous breeds,

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[7] Care should be taken in the interpretation of the climate projections which are in contrast with many other projections for the African continent, and in particular southern Africa. In addition, the marginality of many Namibian households in terms of subsistence farming should be warning enough that climate change is likely to have a marked effect on crop-dependent livelihoods.

smallstock and/or wildlife. Smallstock does not thrive in all Namibian biomes though, and is more prone to theft. As population pressure grows conflicts over resources (the example of the outbreak of Rinderpest in Kenya described above) become more likely.

Bush encroachment has had a discernible effect on the national cattle herd in the past 40 years. With the projected increase of this phenomenon in the relative ‘good’ agricultural zones in Namibia (the north-eastern part of the country) it becomes a matter of national importance to address this issue, ideally seeking solutions to the benefit of the economy. As such, initiatives which utilize the bush should be identified and actively supported.

Population growth and the associated socio-economic stressors discussed in detail in Chapter 2, increased subsistence needs, an endemic dry and variable climate and limited coping ability particularly in communal rangelands (Hulme 1996) are at the core of the vulnerability today, and to future climate change, of Namibian ecosystems.

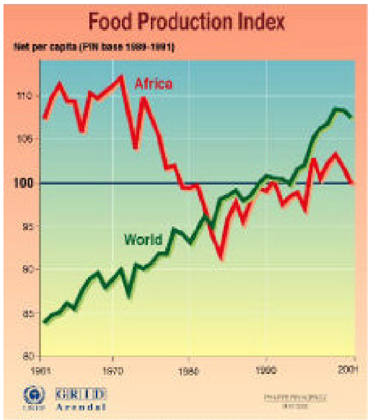
The IIED (International Institute for Environment and Development Environmental Economics Programme) predicts a decline of between 1,1% and 3,1% in Namibian GDP, based on a ‘best-’ and ‘worst-case’ scenario for the country. The activity share of cereal production is likely to decline by between 8,4% and 17%, livestock production is predicted to decline between 19% and 48,4%, whilst traditional (subsistence) agriculture is likely to suffer a decline between 33,5% and 74,6%. Commercial crop production, based on expectations resting on the Green Scheme, is suggested to increase by between 10,2% and 1,3% respectively for the two scenarios. These results are based, in part, on the likely impact of climate change on agricultural production as in Table 4.13 below.

Table 4.13: Likely impact of climate change on agricultural production

Sector	Nama Karoo	Central Areas	North-eastern areas	North-central areas
Livestock	-100%	-35%	-10%	-15% to -30%
Smallstock	-15% to -50%			
Irrigated crops	20%	-15% to 0%	20%	15%
Dryland crops		-100%	-20%	-50%

Source: (Reid et al. 2007)

Food security, in the broader African context, is severely under threat from climate change (refer to Figure 4.23 which depicts the decline in net per capita food production in Africa since 1990 (compared to a net growth for the rest of the World). The FAO projects the need to quadruple food supplies by 2050 to meet people's basic calorific needs, even under the lowest population projections (Elasha et al. 2006).



Source: Food and Agriculture Organization (FAO), Statistical databases (FAOStats), 1995

Figure 4.22: Food production index for Africa and the rest of the World Source: (Elasha et al. 2006)

Food access depends on the ability of households to obtain food from purchases, gathering, current production, or stocks, or through food transfers from relatives, members of the community, the government, or donors. Food access is also influenced by the aggregate availability of food in the market, market prices, productive inputs, and credit. Farmers in communal areas often find themselves in double jeopardy when afflicted by unfavorable weather events, as they often lack the cash to purchase food even if it is available in the shops (S.T. Kandji 2006).

Population growth of 65% by 2030 for the Namibian nation as a whole (the population total is projected to increase from ~1,8 Million in 2001 to ~3 Million in 2031), with a large proportion of society dependent on subsistence farming and with limited education (as discussed in Chapter 2), highlights the importance of off-farm employment creation in the Namibian economy, supported by efforts in the education sector. All those remaining on the land will have to be supported in dealing with our natural variability and climate change though, a topic covered in more detail in the following chapter.

In conclusion to this chapter the following table summarizes the main issues pertaining to climate change vulnerability in Namibian agriculture, depicting whether there is agreement in the model/literature as to the predicted change, the direction (and magnitude where available) of the change; the impact this will have on the agricultural sector in Namibia; and a summary of non-climatic stressors which influence the vulnerability of particularly rural Namibians in agriculture.

Table 4.14 Overview of vulnerability of the agricultural sector to climate change

Climatic Issue	Model agreement	Direction of change	Impact[8]
Maximum temperatures	Yes	• Warming: (increases of between 1°C and 3,5°C in summer and 1°C to 4°C in winter) • Hottest days become more frequent (observations across weather stations in Namibia)	Reduced livestock productivity due to heat stress (based on a multitude of physiological responses/thresholds)
			Increases water demand from livestock, thus reduced grazing distances
			Meat quality reduced due to lack of marbling
			Increased grazing pressure around water points leading to increased erosion
			Higher crop water demands reduces dryland cropping potential
			Increased concerns for animal welfare in intensive industries such as live sheep exports
			Possibly higher vector dispersal and pathogen load
			Animals more susceptible to pathogens due, amongst other, a loss of endemic resistance
Minimum temperatures	Yes	• Warming (frequencies of days with temperatures below 5°C are getting less)	Reduced small-stock mortality due to less severely cold nights
			Increased potential for winter crops (irrigated)
Total rainfall	No: • Information from GCMs for Southern Africa not always in line with downscaled modelling for Namibia • Modelling for Namibia is merely	• Observed historic trends depict a significant increase in the duration of the dry season, shortening of the rainy season and a decrease in the number of consecutive wet days • Projections for the future vary; literature based on GCMs predominantly suggests drying in Namibia as over Southern	Shift in dominant vegetation type from grassy savannah to arid and semi-arid shrubland
			Loss in Net Primary Productivity of Namibian rangelands, as well as forage quality
			Later onset in the season reduces planting windows for crops
			Reduced precipitation in catchment areas of perennial rivers can have significant losses in drainage density
			Increased competition for natural resources by land users
			Decreases in groundwater recharge projected which increase pumping costs and reduce potential for boreholes critical to

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[8] The biophysical interrelations inevitably yield a table were some impacts are derived from combinations of climatic issues.

Climatic Issue	Model agreement	Direction of change	Impact[8]
	conclusive for central and north-eastern regions	Africa; • Downscaled models predict an increase in late summer rainfall over central and north-eastern regions for the mid-century, and; • Predict a drying trend in the Southwest of the country • Downscaled models predict an increase in total rainfall for the late 21st century (data only available for the South of Namibia)	livestock production and management in Namibia
Rainfall intensity	Yes: • Downscaled predictions are an accepted part of climate change projections for Southern Africa	• Trends in increased rainfall intensity in the central area of Namibia are already observed • Downscaled models predict increased rainfall intensity for the mid 21st century, associated with late summer convective rainfall and changes in athmospheric circulation, particularly in central and north-eastern regions (excluding the Cuvelai)	Possibly an increased risk of flooding due to increases in intensity and extreme events
			Effect on run-off, dam yields and groundwater recharge all insecure
			Concentration of rainfall events later in season possible might allows for easier crop management (i.e. timing)
			Possibly higher load of vectors and pathogens on livestock due to increased humidity at times
Evapo-(transpi)ration	Yes	• Increased Evapo(transpi)ration to be expected due to significant warming	Increased algae blooms and salt concentrations in water storage facilities
			Higher crop water demands reduces dryland cropping potential
CO_2			Shift in dominant vegetation type from grassy savannah to arid and semi-arid shrubland
			Projected increase in bush encroachment in North-eastern quadrant of Namibia

Climatic Issue	Model agreement	Direction of change	Impact[8]
Non-climatic stressors (crosscutting)			
Dualism in the agricultural sector makes policy formulation difficult			
Land tenure: lack of collateral in communal areas			
Land tenure: lack of secure tenure rights in communal areas discourages long-term investment and commercialization of agriculture			
Land tenure: high population densities lead to constrained access to fields and grazing areas in northern communal areas			
Limited access to critical inputs in many rural areas hampers agricultural productivity, exacerbated by lack of sustainable land management practices			
Low levels of formal education limit access to off-farm employment and the development of alternative livelihood strategies (e.g. SMEs)			
Limited number of capable institutions in rural areas for advancing, interpreting, communicating and applying knowledge for integrated land and water management in lieu of climate change			
Market requirements regarding frame size (livestock) reduce desirability of indigenous (adapted) breeds			
Unrealistic pressure on agricultural sector to be an economic driver promotes overexploitation of scarce resource base			
Population growth adds to pressure on land and water resources and contributes to conflicts, in particular if high dependence on subsistence agriculture persists.			
HIV/AIDS decreases life expectancy and increases morbidity and the number of dependents and orphans that households have to support. This has a negative impact on financial and human resources and labour productivity, with potentially negative impacts for food security.			
Capacity for social organization and support in communities in various regions of the country appears to be dwindling			

5 Adaptation to climate change in Namibia

5.1 Introduction

Adaptation to climate change is the process, or outcome, to improve society's ability to cope with changes in climatic conditions across time- and policy scales. The IPCC (2001) defines adaptive capacity as the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (Nhemachena and Hassan 2007). Adaptation can be either a specific action (such as changing the crop grown); also termed autonomous adaptation (FAO 2007), or a process (such as creating a conducive environment allowing farmers to respond to change) also termed planned adaptation (FAO 2007). Adaptation can also be a systematic change, such as institutional reforms changing tenure rights to promote investments.

The high vulnerability of Africa to climate variability and change can be attributed to both high levels of climate variability as well as *low adaptive capacity*. A number of factors contribute to this low adaptive capacity including a deteriorating ecological base and a high dependence on the natural resource base, widespread poverty, inequitable land distribution, and the ravages of HIV/AIDS (Hulme 1996; Elasha et al. 2006).

This chapter deals with adaptation to climate change for both the agricultural and water sectors, as touches on adaptation to climate change in the energy sector in rural areas as a cross-cutting issue.

5.2 Adaptation to climate change – the crop and livestock sectors

The IPCC (2007) classifies adaptive responses to climate change as technological, behavioral/ managerial, or policy oriented. This section is structured along these topics, yet it is imperative to acknowledge that the highest chance of success is achieved where these areas overlap; bringing together technological improvements, stimulating behavioral change, developing institutional backing and capacity and all enveloped by a conducive policy environment.

5.2.1 Adaptation to climate change – Technological

Agricultural adaptation in general involves two types of modifications in production systems. Increased diversification involves engaging or changing production activities in order to increase the likelihood of agricultural success in the face of changing climatic variability. In arid environments, this may include drought and/or temperature tolerant species, or any other activities that make efficient use and take full advantage of the prevailing water and temperature conditions, among other factors. Crop diversification helps dealing with the impact of environmental conditions as different crops are affected differently by climate events. Management practices can be adapted to ensure that critical growth stages are less impacted by harsh climatic conditions such as mid-season droughts or temperature peaks, as discussed further down. Crop management practices that can be used to reduce exposure to shortening seasons include modifying the length of the growing period and changing planting and harvesting dates. The sensitivity of livestock breeding seasons to temperature stress has been discussed in the vulnerability chapter. Management adaptations can plan around these periods of heightened impact, which are discussed further down.

5.2.1.1 Irrigation, conservation techniques and improved seeds

Use of irrigation has the potential to improve agricultural productivity through supplementing rainwater during dry spells and lengthening the growing season, yet irrigation water is also subject to impacts from climate change. Use of irrigation technologies need to be selected to maximize water efficiency and to be accompanied by other crop management practices such as use of crops with high levels of water use efficiency. Discussions with the GSA have identified Namibia's key areas of further research which include research aimed at drought-adapted plants, including Genetically Modified (GM) crops, water efficient technologies, scientific understanding of climate and soil water storage technologies.

Soil and water conservation practices offer opportunities for adapting to decreased precipitation and increasing temperatures. This is particularly important in Namibia where water and high quality soil are scarce resources. Conservation tillage has the potential to improve soil characteristics, water infiltration and retention. Additionally, the decreased labour demand of these practices can help households cope with strained labour resources that are a result of rural migration and HIV/AIDS.

Figures 4.3 to 4.5 in the previous chapter depict the very low adoption of improved seed varieties and fertilizer application amongst farmers in the Caprivi region. When incorporated with soil and water conservation practices and supported by a regular supply of specialist advice and crucial inputs, changes in crop husbandry practices could significantly improve crop yields, and hence household food security, in rural areas of Namibia. Cropping a mix of various staple and cash crops allows a certain degree of hedging against low rainfall events and/ or shorter seasons supports household food security whilst allowing for possible sales of higher value crops.

5.2.1.2 Indigenous breeds and herd composition

As discussed in Chapter 4, the adaptive traits of indigenous breeds (ability to cope with heat both for production and reproduction, walking ability and others) provide significant advantages for selection of these stress resistant species in the livestock sector. Herd composition, which allows for more flexibility during drought (as destocking sales can be easier realized with, for instance, a lower proportion of mother stock), as well as reduction in herd sizes that increases the proportion of quality, young and heat tolerant stock are adaptation strategies that enable livestock producers to pursue their trade even as climate change takes its toll.

Ultimately, in farming systems dominated by extensive livestock production enhancing natural plant cover in itself provides not only one of the more suitable adaptation mechanisms, but acts an internal feedback system as to the state of the environment with land cover acting as an indicator of land management. The natural plant cover in Namibia has another strong advantage having adapted to uncertainty/variability over time, a endemic resilience which can not be developed or replaced rapidly by changes to the farming system. It is this comparative advantage, as well as traditional coping mechanisms from the land management perspective (such as practicing of transhumance), which should be harnessed to identify contemporary local responses which work and have worked in the face of climate variability. The additional benefit of thus demystifying climate change and adaptation for local resource users is invaluable in reaching the most important group.

5.2.1.3 Infrastructure

Water harvesting and storage at the household and regional level is of cardinal importance for agricultural production, especially when considering increased crop and livestock water demands that are expected under climate change. This issue is further explored in the section on water adaptation. Infrastructural developments can play an important role in de-coupling livestock production from external climatic factors, and hold particular promise in intensive systems (such as dairy, chicken and pork production) but can also mitigate the impact of the worst heat and other extremes in extensive systems. The potential for feedlots in lieu of the Green Scheme project sites can also reduce the dependence on extensive grazing systems in Namibia, and contribute to the policy goal of local value addition.

5.2.2 Adaptation to climate change – Policy

Policies in support of adaptation to climate change can be divided into two categories: those intended to increase the exercise of the best technical options (thus the adoption rate) available at any given time, and those aimed at improving the set of such options over time (Rosina et al. 2007). Following a brief policy review in the agricultural sector with emphasis on climate issues these two categories are discussed. Arguments for the importance of mainstreaming climate change as an issue of development, rather than considering it only from an environmental vantage point, are made. The complexity of this is acknowledged, and some selected opportunities which arise due to climate change are alluded to.

5.2.2.1 Policy review – agriculture, water and climate variability

Namibia’s policy framework is laudable, as the following summary of key policies will show. Alas, living up to the noble goals has proven to be more difficult.

The National Agriculture Policy (NAP) (Republic of Namibia 1995) was formulated within the overall national development objectives set out at Independence. These included the alleviation of poverty and a reduction in income inequalities. The overall goal of the Policy *‘is to increase and sustain levels of agricultural productivity, real farm incomes and national and household food security within the context of Namibia’s fragile ecosystem’*. In terms of the NAP, government’s main role will be to create a favourable macro-economic policy environment and to provide agricultural support services and facilities conducive to increasing and sustaining agricultural productivity, real farm income and food security. Due to resource constraints, government will limit its development efforts to provide essential services. These services will be designed to redress the structural imbalances and dualism inherent in the sector ‘by redirecting and strengthening essential services and facilities to the communal areas, where their socio-economic impact is likely to be greatest’. Effective drought preparedness planning and responsive drought management are considered to be a key factor; the production of staple foods will be encouraged in order to achieve household self-sufficiency and food security. Agricultural extension is to play a coordinating role in ensuring that farmers have access to support services and programmes for improved farming and marketing practices. The main focus of extension services will be on small- and medium-scale farmers, with particular emphasis on, amongst others, supporting female headed households. Government will avoid long term and continuing subsidies as they are likely to cause distortions in the economy. The establishment of national savings and credit schemes will be encouraged to encourage subsistence farmers to increase the production of food stuffs and become surplus producers. Government undertakes to provide financial support to farmers who will not qualify for commercial credit. Government will also consider practical ways to integrate and coordinate rural and regional development programmes aimed at addressing such problems as rural poverty, food insecurity and the unequal distribution of incomes.

The NAP thus makes provision, on paper, to

- target the more vulnerable groups (e.g. small-scale communal farmers, female headed households),
- improve food security,
- ensure coordinated development programmes,
- establish credit schemes and assist where lack of collateral bars access to credit, and
- avoid perverse incentives in lieu of climate variability but address crisis situations.

Namibia’s overarching Vision 2030 emphasizes environmental constraints to sustainable agriculture. It states: *“In Namibia, surface water is scarce, availability of grazing is variable and livestock carrying capacity is low. These natural environmental constraints severely limit the development of rain-fed cultivation and commodity-farming throughout most of the country….Considering the low capability of the land for husbandry, it is not surprising that Namibia’s agriculture sector is subject to uncertain output, regular crop failure and a drain on state finances, through heavy subsidies and drought relief.”* This glum summary of the sector is in direct conflict with for instance the National Agricultural Policy which, along with many other policies, states that the sector should be a key driver of the economy.

In 1997 the GRN developed a new Drought Policy and Strategy. Previously a number of these relief measures such as fodder subsidies were found to encourage unsustainable farming practices, and food distribution to vulnerable groups was inefficient and poorly targeted. Government support created a *moral hazard* in that it fostered an expectation that in cases of drought, government would come to the rescue. This approach, in turn, encouraged farmers to adopt risky farming practices like overstocking and farming on marginal land. The new approach to droughts is based on developing an efficient, equitable and sustainable approach to drought management. This implies shifting the responsibility for drought management from government to farmers. However, the Policy provides for poverty related food security interventions - food or cash for work, school feeding schemes, food distribution to vulnerable groups - in support of the extremely poor to be extended in times of disaster droughts ‘according to determined needs’.

The National Water Policy (NWP) (Republic of Namibia, 2000) was formulated and approved to address inequalities in access to water. In line with other government policies, the NWP puts places more responsibilities on community management of water supplies. The policy is built on the assumption that privatisation of water service ‘can introduce efficiency and effectiveness, reduce wastage and extend use of valuable public funds’. Cost recovery and economic efficiency are accorded high importance.

The NWP tries to balance the imperatives of improved equity with sustainable water management, economically and environmentally. It states that ‘all Namibians have the right of access to sufficient safe water for a healthy and productive life’, while, at the same time, recognising the scarcity and economic value of the resource. Decentralisation of water management and development, as well as integrated planning with the aim to establish socially and environmentally sustainable practices are some of the fundamental principles of the NWP. In line with this decentralised water management structures have been established in all regions. An important role in this regard is attributed to Basin Management Committees which will be responsible to manage a water basin within an integrated management plan. At the local level, Water Associations and Water Point Committees will be responsible for the day to day management of water points. The role that Basin Management Committees could play in water resource management in the context of climate change is evaluated later in this chapter.

The Poverty Reduction Strategy (PRS) for Namibia, published in 1998, identified six structural problems that make poverty reduction difficult and which exacerbate vulnerabilities to climate change as well as limit adaptive capacity of Namibians. The structural problems included: a) a highly skewed distribution of income, b) a weak agricultural resource base, characterized by limited and highly variable annual rainfall as well as sandy soils with low fertility and c) a high population growth rate and the resulting pressure this puts on scarce resources such as water. The PRS nonetheless recommends that the livestock sector be further developed and crop productivity and value be increased. New ways of using water more efficiently are considered important, and the PRS importantly promotes diversification out of traditional agricultural land use systems. The PRS was translated into the National Poverty Reduction Action Program (2002), which focused on four pillars:

- Long-term macro-economic development by focusing on Namibia’s role as a transport and manufacturing hub and by investing in health and education
- Broadening the scope for alternative income generation in agriculture, tourism and SMEs
- Strengthening Namibia’s safety net for the poor and vulnerable through grants and labour intensive works
- Strengthening the capacity for participatory democracy and decentralisation

A review of the PRS and NPRAP underscored that environment, gender and HIV/AIDS could have been more strongly integrated in the original strategy and action program. In terms of environmental change, the strategy and action program merely focused on income generation through the CBNRM program rather than on adaptation to the highly variable climatic conditions in Namibia (Republic of Namibia 2005).

Adaptive capacity to climate change is also influenced by a number of other policies matters as alluded to in Chapter 2. Policies certainly exist regarding the ownership of land, HIV/AIDS, gender, decentralization, and education; although notably no rural development policy for Namibia has been developed to date.

In line with some of the recommendations of the review of the PRS and NPRAP, considerable efforts have been made by the government to mainstream environment and sustainable development issues (as well as poverty, gender and HIV/AIDS) in NDP3, the next five year development plan on the way to Vision 2030. Drought, floods, extreme events and climate change was considered one of five blocks with ‘top’ environmental topics to be mainstreamed (Zeidler 2007). The onus is now on government and other service providers to realize the set goals and objectives in the next five years.

A number of policies that are relevant are to climate change are thus in place, and most are considered as of high quality. Understanding of these policies, as well as subsequent implementation and coordination between sectors and within sectors is often sadly lacking though; as is a common vision of what the sectors real role is/can be in future as underscored by Seely et al. (2008). The newly established Country Pilot Partnership (CPP) Program for sustainable land management however provides a practical opportunity to translate policies into practice, as it serves as a vehicle of continuing the momentum gained under the Namibian Program to Combat Desertification (NAPCOD).

5.2.2.2 Increasing the exercise of best technical options

In order for appropriate adaptation options to be adopted, policy is often needed to encourage uptake. This can be supported by *increasing the exercise* of the best technical options available at any given time which could include analysis of and education about the options (such as developing an in-depth understanding of climate change impacts on a sector *per se*, and sharing the information*)*; correction of perverse incentives; financing for targeted options which are deemed critically important to improve adaptive capacity; performance and portfolio standards; and subsidies for targeted options. The lack of financial resources amongst rural communities for instance has been highlighted in earlier chapters, and is a major obstacle for adaptation implementation even outside of Namibia (Nhemachena and Hassan 2007). The lack of collateral often accompanies low adaptive capacity, which puts poor households in double jeopardy. Improved (access to) insurance schemes, access to finances as well as access to factors of production will greatly contribute to the higher levels of resilience amongst rural Namibians so desperately needed in the face of climate change.

At the macro-level Hassan (2007) found that access to credit, free extension services, farming experience, mixed crop and livestock farms, private property and perception of climate change proved important for households to increase resilience to climate variability and change. Investing in the development of adapted crop varieties has yielded major returns for Namibia according to CIMMYT (International Maize and Wheat Improvement Center), which claims that the return on investment in the development of the pearl millet variety Okashana 1, was 50% and amounted to US$ 11 million in 1998 alone (Kandji S.T. 2006). Considering that the access of seeds is the major barrier for widespread adoption, innovative options such as joint venture of seed producers and public benefit companies should be pursued.

Central to improved adoption of options/changes to behavior throughout society is the challenge of properly communicating climate change; be it to policy makers, resource users of urban populations. Namibia should identify/devise the right messages and channels to reach the various groups in an effective manner if any change as considered important is to be induced, particularly if efforts are to be preventative rather than curative.

5.2.2.3 Improve the characteristics of available options

Policy measures intended to *improve the characteristics of the available technical options* over time include improving capabilities for research, development, and demonstration; encouraging/ funding these with tax policy and other policies; promoting niche and pre-commercial deployment; and international transfer of resulting technologies (Rosina et al. 2007). The UNEP funded "Assessment of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors" (AIACC) suggests that "enabling the process of adaptation is the most important adaptation that the public sector can make" (N. Leary 2006). The provision of public goods such as extension, training, and credit as well as addressing tenure security as well as land size, can help to support the process of adaptation and thus play a major role in facilitating improved climate change adaptation (Nhemachena and Hassan 2007).

One of the shortcomings of adaptation in the Namibian context is the lack of coordination between parties; the donors amongst themselves, GRN and the donor fraternity, sister ministries and even departments within a particular Ministry. The lack of collaboration leads to inefficiencies, contradictory messages and heightened time requirements on both public servants and, more importantly, rural communities. For example, sporadic free seed supply is provided by donor support, but ultimately establishes a strong barrier for private sector involvement on improved seed supply. Efforts by institutions and policy makers alike to address this issue would be even more critical if 5.3.2.3 below was to be achieved.

5.2.2.4 Integration of adaptation to climate change into the national development agenda

Climate change should be streamlined into the core of the Namibian development agenda. The difficulty the authors of this report experienced in setting the boundaries of *where* climate change vulnerability can be drawn (compared to the whole host of vulnerabilities Namibians face) emphasizes the entrenched link between the topic at hand and the challenge of development at large, and the complexity of this.

It is important to recognize that some ‘development’, in its many guises, can contribute to vulnerability, especially if it leads to mal-adaptation or to some groups becoming worse off from certain adaptation strategies. Trade liberalization, for instance, can bring general increases in economic activity, lower prices, and greater overall wealth, but the benefits are often unevenly distributed; Namibia is a case in point. In particular smallholder farmers, who have little access to lucrative markets, struggle to compete with commercial counterparts because output prices lag behind the costs of inputs and make the farmers more vulnerable to climate shocks. The high level of dependence on public goods because of the lack of private sector investment in low-input / low-output farming systems also creates an additional stressor on communal farmers, further reducing their resilience to climate change.

Furthermore, climate change should be included/ integrated into the National Development Agenda because changing environmental conditions, particularly in lieu of climate change, are expected to further reduce the productive potential of marginal lands. With reduced productive potential, marginal lands may loose some/ a lot of the capacity to sustain livelihoods of resource-poor rural populations. This circumstance will augment the rate of urbanization, which can be expected to present a host of challenges for local authorities that may range from meeting growing demand for food on small parcels of land, water supply management, waste management and sustainable energy use and supply. Small towns have minimal capacity to cope with higher population densities because of limited economic opportunities. The desired ‘balanced’ urbanization as described in, amongst other, Vision 2030 is in jeopardy because of very high levels of unemployment in small towns and the rural exodus focuses primarily on the capital and few selected cities.

5.2.2.5 Opportunities

The reality of living in a variable climate, with the added pressures of a changing, and certainly increasing variability in climate, is that along with the challenges there are also opportunities.

Urbanisation, when associated with the entrance into the formal economy, has a dual benefit in the sense that both essential services can be supplied and targeted in a more cost-effective manner (e.g. provision of clean water in a suburb vs. in a remote village), and that some of the market entrant will pay taxes and increase public revenue.

The existence of the Clean Development Mechanism (CDM), and recent policy decisions in Namibia to establish a unit in the DEA to allow Namibian projects to benefit from this transfer mechanism, offers a great opportunity for rural Namibia to engage in the global trend of expanding the use of biofuels, especially in the energy and transportation sectors, through energy portfolio standards and incentives to growers[9] and consumers. The bush encroachment problem in particular could become an opportunity with the implementation of rapidly developing biomass-to-liquid technologies, and energy farming a new driver of the Namibian rural economy. CDM projects should also look at promoting reforestation, afforestation, and improved land-use practices in ways that enhance overall productivity and delivery of ecological services while simultaneously storing more carbon and reducing emissions. Clearly, any such interventions warrant careful attention to environmental impacts, biodiversity concerns, and energy and water inputs; the debate on the merits of biofuels is well documented in the media.

Namibian experience with Community Based Natural Resource Management (CBNRM) has provided an opportunity for communities to diversify traditional systems as a source of revenue for rural communities. At the same time, this provides an opportunity to integrate adaptation to climate change when responding to other changes in the environment or socio-economic environments. CBNRM in addition fosters the devolution of decision-making to the local resource users, strengthens institutions on the ground and allows for much better choices regarding resources compared to centralized systems of decision-making. The continuous shift towards game farming in the commercial farming areas reflects the realization of the opportunity to harness the environmental and economic potential of the highly adapted wildlife in rural Namibia.

Policy makers need to respond to the AIACC recommendation of '*promoting action today*' in order to prevent incurring much higher costs in the future. Conservation is known to be cheaper than restoration, and the recommended way to go about climate change adaptation is to tie it into the development agenda.

5.2.3 Adaptation to climate change – Institutional and household level behavioural/ managerial changes

Adaptation at the farm-level focuses on tactical decisions farmers make in response to seasonal variations in climatic, economic, and other factors. These tactical decisions are influenced by a number of socioeconomic factors that include household characteristics, household resource endowments, access to information (seasonal and long-term climate changes and agricultural production) and availability and access to formal institutions, including input- and output markets. Farm-level decision making is driven primarily by the short-term, usually influenced by seasonal climatic variations, local agricultural cycles, and other socio-economic factors. This section will further elaborate on the importance of perceptions of climate change and communication and information dissemination.

5.2.3.1 Perceptions of climate change

Perceptions of changes are as critical as knowledge of change; in the absence of clear messages perceptions become paramount in the decision-making process of land users. IFPRI analyzed farmer perceptions to climate change on long-term changes in Southern Africa (South Africa, Zambia and Zimbabwe). Over half (51%) of the respondent farmers expected increased temperatures in the future (with nearly a third anticipating no temperature changes)

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[9] Harvesting invader bush is, in the short term, much less dependant on rain than growing crops for instance, and in the long term provides a real adaptation mechanism restoring the productivity of Namibian rangelands.

and 45% anticipated reduced precipitation in future. 40% of the respondents are not adopting any adaptation strategies (Nhemachena and Hassan 2007).

The most prevalent adaptation measures selected by the farmers in the survey included: planting of new varieties, planting at different times, diversifying into non-farm activities and increased use of water where most prominent. The authors acknowledge that these actions "might be profit-driven rather than responses to climate change" (Nhemachena and Hassan 2007); again the strong correlation between climate change and development is visible. The poorest section of rural communities engage in opportunistic gathering of wild products, but even this adaptation strategy depends heavily on the natural environment (Kandji S.T. 2006). The lack of credit, lack of information about both short-term variation and long-term climate change, insufficient information regarding adaptation options and the lack of seed inputs where amongst the most important constraints for southern African farmers according to IFPRI (Nhemachena and Hassan 2007). Amongst these the lack of credit was mentioned by the largest part of respondents (30%) as the most serious barrier.

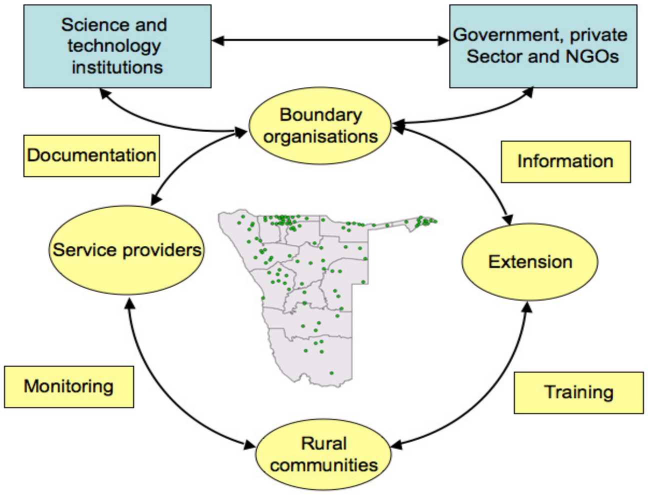
5.2.3.2 Improved communication and translation of information

At the institutional/ technical level better forecasting and Early Warming Systems should be established in order to guide behavioral adaptation, which could increase adaptive capacity on an annual basis and, in time as capacity is built and data becomes available, also increase adaptive capacity over the longer term. A lack of access to information including the historical climate, projections to future climate change and potential impacts, estimates of climate risks, technologies and measures to manage climate risks and know-how for implementing new technologies is highlighted (Leary et al. 2006). Advancing, interpreting, communicating and applying knowledge should be fostered, and Namibia has in fact ample experience in various sectors (such as with Basin Management Committees, FIRMs and other approaches) which should be strengthened and broadened to deal with climate change.

Improved communication about the risk of climate change in Namibia should enhance the incentive for adaptation implementation. A variety of adaptive practices are already in use but in most cases these measures have been adopted in response to multiple sources of risk and only rarely to climate change alone. One strategy commonly in use is to increase the capacity to bear losses by accumulating food surpluses, livestock and other assets. Locally the accumulation of livestock is considered particularly important, although issues such as status associated with owning big herds seem to be the prime motivation (and, in effect, largely contribute to environmental degradation). Exposure to climate hazards has been reduced by relocating, either temporarily or permanently. This adaptive measure is practiced year-in year-out in regions such as Caprivi in response to floods, yet it has to be acknowledged that climate change is likely to make this strategy less robust as extreme events are likely to occur much more frequent. Risk spreading is accomplished through kinship networks and disaster relief.

Many post-independence development efforts aimed to contribute to the capacity to adapt to liking in a variable environment are enabled by public sector assistance such as extension services, education, and community development projects, which enhance communication and information dissemination. Nevertheless, in a context of climate change and increased pressure on local resources there is a major need for improving social organization and local adaptive capacity, as the PPAs in Caprivi, Karas and Hardap underscored that there is limited organizational capacity, dwindling social support and a fair amount of conflict in Namibia's communities. The exchange of information between service providers and communities also leaves a lot to be desired. Boundary organizations (as in Figure 5.1 below) are needed in order to interpret and communicate information from scientists to practitioners and the public. It is important that this climate information can be easily understood and accessed across sectors and from local to national and international actors. These boundary organizations and associated networks should link research to policy-making, with an emphasis on getting research messages to appropriate target groups. It is also important that research is linked to existing local knowledge of climate related hazards and involves local communities in exploring adaptation decision making. There is a need for effective communication between the supply-side and demand-side communities of climate information in Africa, and the need to work on means by which climate information can be incorporated into the livelihood strategies of potential users.

Figure 5.1: Advancing, interpreting, communicating and applying knowledge for integrated land and water management



5.3 Barriers to adaptation

People may not adapt sufficiently to climate change for a variety of reasons. Climate may be perceived to pose little risk relative to other hazards and stressors and therefore given low priority, which becomes quite clear when reading Chapter 2 and the Namibian Poverty Profiles. Knowledge of options to reduce climate risks or the means to implement adaptation measures may be lacking. Expected costs of adaptation may exceed the expected benefits, especially if these have not been quantified as is the case in Namibia. Uncertainty about the future, as highlighted throughout the report, may make it difficult to decisively implement adaptation measures in a specific time frame. Irreversible consequences of some adaptations may delay choices until some of the uncertainty is resolved. Incentives may be distorted in ways that may either discourage choices that reduce risks or encourage riskier choices; drought aid for instance can perpetuate overstocking if not implemented well. Sometimes the action or inaction of others can be an obstacle to adaptation at the local level, an issue of critical importance in open access resource regimes. Some may believe that reducing their own risk is the responsibility of others, particularly the Government (N. Leary 2006).

Barriers to adaptation can also arise when proposed measures are not technically feasible, when they are not socially accepted, when their effectiveness has not been demonstrated, when they are not economically viable, when institutional capacity or human skills are lacking; when measures are not compatible with existing policies, and when transboundary issues are involved. (Rosina et al. 2007).

A Namibia specific Assessment into technology needs for mitigation and adaptation, prepared in 2005 for the MET, differentiated between the following barriers to adaptation to climate change in Namibia (each very briefly elaborated):
- Insufficient awareness (information limited to specialists and access to research by stakeholders)
- Political and institutional barriers (implementation of policies, low public participation)
- Socio-cultural barriers (technology stigmatation and techno-focus, as well as a different local priority than national ones at times)
- Financial barriers (types and conditionality of funds, insufficient pricing of resources, and a lack of access to private funding)

5.4 Energy and adaptation to climate change in rural areas

As of 2007, power capacity shortages experienced in southern Africa (Electricity Control Board 2006) are indicative of the looming energy crisis in southern Africa. Not only does the crisis complicate the already substantial challenge of electrification throughout the region, but it has cross-sectoral ramifications as a result of the link between energy and economic development. Given the imminent, widespread threat of such a crisis, adaptation that accounts for the impact of climate change in the energy sector is a matter of the highest urgency.

Adaptation in the energy sector can take place on the production side, the consumption end or, preferably, both. Energy production adaptation works towards long-term energy security—a perspective that must promote the use of renewable and energy efficient production technologies and relieve the dependence on non-renewable, volatile and environmentally unsound resources. On the other hand, energy consumption adaptation focuses on the mitigation of energy demand through the use of energy efficient and renewable energy devices and technologies.

With low levels of rural electrification, natural resource management and access to renewable energy and energy efficiency technologies are at the core of energy security issues for the 65.3% of the Namibian population who live in rural areas (Republic of Namibia 2006). However, Namibia’s low population density and the remote location of rural communities require significant investments in grid-electricity infrastructure development and maintenance. Consequently, small-scale, renewable power production, such as solar, wind, and biomass based electricity generation, proves to be the only viable way for Namibia to achieve widespread electrification.

Additional priority measures to promote energy-related adaptive capacity in the face of the observably increasing climate variability include: initiatives that relieve the dependence on climate influenced fuel sources, such as firewood, and strategies to increase the buffer between the internal and external household environment. Dependence on vulnerable fuel sources can be relieved through use fuel efficient stoves and cookers and solar home technology. Many building materials and design options, such insulation, ceilings, shading, and building orientation, substantially decrease the degree to which households are influenced by external climate conditions and the efficiency of internal space heating and cooling.

5.5 Adaptation to climate change in the water sector

In view of the arid and highly variable climatic conditions in the country, water resource managers in Namibia have focused their attention on improving efficiency of water resource use. Temperature increases associated with climate change predictions for Namibia imply that evaporation will increase by about 15 percent. Although there are indications of increased convective rainfall in the late summer season, as well as a shortening of the rainy season, the downscaled GCMs and RCMs have not provided a conclusive picture in terms of the amount of rainfall in Namibia in the future. Water demand projections –not taking climate change into account- indicate that demand will have surpassed the installed abstraction capacity by 2015. In terms of water resource management the combined impact of climate change, population growth and development imply that there needs to be continued attention for dealing with evaporation and thus for improving efficiency of the utilisation of water resources. This can amongst others be realised by the conjunctive use of water resources and through improvement of water demand management practices.

5.5.1 The conjunctive use of surface and groundwater resources

Water managers in Namibia have experience with the conjuctive use of surface and groundwater resources. The conjunctive use of water means that surface water and groundwater are used together with the aim to minimise evaporative losses. This can be realised in a variety of ways. First of all, artificial recharge of an alluvial aquifer can be realised by collecting runoff in a reservoir just upstream of the aquifer. Such a facility has already been built at the Omdel dam on the Omaruru river.

In view of increasing water demand in the central area of Namibia, the Ministry of Agriculture, Water and Forestry and Namwater have explored other ways of conjunctive use (Central Area Joint Venture Consultants 2004). A first option is to use groundwater resources as a reserve or back-up for the abstraction of a surface water source, in order to allow a higher rate of abstraction from the latter. Surface water is used at a faster rate and this reduces evaporation losses and thereby increases the efficiency of the surface water source. An example of this type of conjunctive use is to utilise the Tsumeb Karst Aquifer as a back for the supply of three major dams (Omatako, Von Bach and Swakop dams) in the Central Area of Namibia. This option for conjunctive use has not been applied yet, but would increase the 95% safe yield of the three dams from 16 to 25 Mm³/annum (Heyns 2007).

A second and very innovative manner of conjunctive use consists of water banking or managed artificial recharge, which has started on a small scale in the Windhoek Aquifer. It means that surface water from the Von Bach dam is purified in a water treatment plant and stored underground in the Windhoek Aquifer. This results in lower evaporation and overflow losses at the dam and in years that the surface water sources (the 3 dams in the Central Area supplying Windhoek) cannot deliver sufficient water, stored underground water can be extracted. Thus, the proposed system uses existing water resources more efficiently and secures a larger supply of water (Central Area Joint Venture Consultants 2004; Heyns 2007).

Current water demand in Windhoek stands approximately at 21 Mm³/annum. The long term sustainable safe yield from the aquifer is only 1.7 Mm³/annum, whilst average abstraction since the 1950s amounted to 2.1 Mm³/annum. This implies that reclaimed water and water of the Von Bach dam are important water sources for Windhoek and that the storage of groundwater in the Windhoek Aquifer has been reduced over the decades. In view of fluctuating supply by the Von Bach dam, a project is underway to gradually improve the capacity to recharge the Windhoek Aquifer from the present rate of 3.2 Mm³/annum to a rate of 8 Mm³/annum. If all phases of the project would be implemented over a period of 15 years, this would enable expansion of the storage capacity of the Windhoek Aquifer from 35 to 66 Mm³ thereby securing water supply in the Central Area of Namibia (Van der Merwe 2006; Heyns 2007).

(Central Area Joint Venture Consultants 2004) compared the cost of water banking in the Windhoek Aquifer with conjunctive use of the Tsumeb Karst area and extension of the ENWC to the Okavango river, and further undertook a financial and economic cost-benefit analysis.

Table 5.1: Comparative costs and cost-benefit analysis of water augmentation options for the central area of Namibia (in million N$ - 2004 prices).

Indicator	Windhoek Water Banking	Tsumeb Karst Area	Extension of ENWC to Okavango	Extension & Windhoek Water Banking
Capital Cost	126	182	1,183	435
Financial CBA				
• NPV (8 %)	- 37	-95	- 673	-399
• IRR (constant prices)	-2.8 %	-4.0 %	-4.2 %	-5.6 %
Economic CBA				
• NPV (8 %)	102.6	NA	NA	NA
• IRR (constant prices)	6.0%			
Water cost (N$/m³)	6.72	16.88	141.27	33.05

Source: after (Central Area Joint Venture Consultants 2004; Heyns 2007)

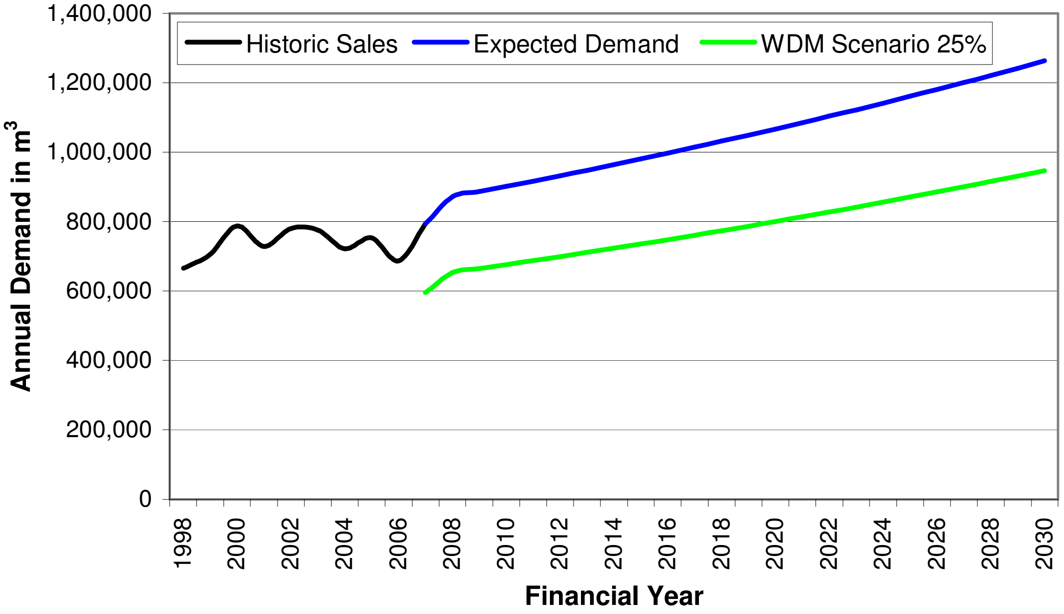
None of the water augmentation options for the Central Area of Namibia was found financially viable, due to the fact that water banking in the Windhoek Aquifer, or any of the other schemes, will only improve the security of supply. It will however only result in revenue from water sales during periods of drought and water shortage in the Central Area Network. Out of the four options explored, water banking in the Windhoek Aquifer was nevertheless considered the best option, since it is the most cost effective one. An economic CBA further underscored that the project is economically viable if one considers the effects of the scheme for Namibia as a whole. The economic CBA particularly provides an indication of the negative impact on Namibia's economic growth in case a 1 in 25 year water shortfall would arise in the Central Area. In addition, managed artificial recharge of the Windhoek aquifer has other benefits (Central Area Joint Venture Consultants 2004; Van der Merwe 2006):

- The size of future augmentation schemes foreseen as extension of the ENWC can be downsized significantly (e.g. Okavango river abstraction)
- Upgrading of bulk water supply infrastructure may be postponed if the water bank is fill in off-peak periods, allowing high abstraction in peak periods
- The environmental impacts are minimal compared to the alternative options
- There are positive impacts in terms of the contribution to the GDP and employment creation.

5.5.2 Water Demand Management

Water demand management (WDM) is part of an integrated approach towards sustainable use of water resources. The main purpose of WDM is to reduce wastage and to enhance the efficient use of water. This entails a reduction of losses and volume of water used to perform a particular task, without sacrificing the level of customer service. For example, the use of a low flush toilet and an efficient shower head does not influence the level of service to the user. Examples of demand management measures include conservation-oriented pricing, reduction of non-revenue water, pressure reduction, water-efficient landscaping, changes in water use practices, and public education (Namwater 2007). Given the prevailing arid climatic conditions in Namibia, the introduction of WDM-measures has already been propagated by (Heyns et al. 1998). With the uncertainties involved in climate change predictions for Namibia, WDM makes sense as a "no regrets" type of investment. Although WDM is not a substitute for supply augmentation in a developing country such as Namibia, it can contribute to cost savings by deferring the capital infrastructure, expenditure and a reduction in operational costs.

Figure 5.2: Mariental water demand (1998-2030) according to scenarios with and without WDM



Source: (Namwater 2007)

WDM is especially relevant for the management of non-revenue water in local authorities of Namibia, as a considerable number of towns and settlements are faced with substantial losses due to pipe breaks, leaks, inaccurate water meters, un-metered and illegal water connections, as well as administrative losses (see also chapter 3). (Van der Merwe et al. 2005) describe that a pilot with WDM in Rehoboth led to a reduction of non-revenue water from 0.6 Mm³ to 0.17 Mm³ between 2000/2001 and 2002/2003, whilst overall demand for water in this town was reduced from 1.82 Mm³ to 1.54 Mm³ in the same period. Measures introduced comprised capacity building in managing leakages in the reticulation network, the introduction of a credit control system and equitable water and sanitation tariffs, as well as improved communication to the community. As a result of these measures outstanding debts by water consumers was reduced with more than 3 million N$ between 2002 and 2004. This was amongst other attributed to the involvement of the community in decision making on tariff setting and credit control.

A recent Namwater study elaborates the potential effect of the introduction of WDM on demand for water in towns and settlements in Central South Water Supply Area (CSWSA) towards 2030. It indicates that WDM can contribute to a reduction in current and future demand of approximately 25 percent, as Figure 5.2 depicts (Namwater 2007). The report further suggests that in a number of towns and settlements in the CSWSA investment in expansion and upgrading of physical infrastructure can be delayed when WDM measures are introduced. An essential aspect of the suggested WDM measures is the introduction of a so-called conservation tariff, which means that higher rates are paid by consumers who use more water, so that demand for water can be managed and even reduced. In addition cross-subsidisation of low-income earners by means of a rebate system is part of the WDM pricing system in order ensure equitable access to water, as well as to enhance compliance with paying for water by poorer segments of society (Van der Merwe et al. 2005).

5.5.3 Groundwater Monitoring and Control

Given that about 45% of the water used in Namibia is abstracted from groundwater, it is important to expand efforts of the MAWF to keep track of groundwater water levels across the country. This is all the more relevant as the population is expected to grow to 3 million persons towards 2030 and in view of an anticipated increase in industrial demand. The government has already embarked on monitoring groundwater levels, in particular in so-called groundwater control areas, where aquifers are not that productive or finite in nature. Predicted increases in evaporation under future climate conditions may, depending on dam characteristics, affect the supply of surface water. As a result of this the necessity to rely on groundwater in Namibia’s interior is likely to increase. To ensure that abstraction of groundwater is undertaken in a sustainable manner, government’s efforts to monitor groundwater levels would need to be increased to all eleven basins (Heyns et al. 1998).

5.5.4 IWRM and Basin Management Committees

The government of Namibia considers Integrated Water Resources Management (IWRM) as an important manner in which sustainable use of water resources can be ensured. Within the IWRM concept the basin is considered the key entity at which the management of natural resources can be discussed and negotiated between stakeholders. The government further strives after full recovery of the costs involved in delivering water to consumers and intends to integrate the local water point committees in basin management structures. These policy objectives are supported by various policy frameworks such as the Water Supply and Sanitation Sector Policy of 1993, the National Water Policy (2000) and the Water Resources Management Act of 2004, and further by the Constitution of Namibia and by the CBNRM program. In practical terms there are 24 river basins in Namibia, which have been grouped into 11 basins for management purposes; in 4 basins management committees have been established.

In terms of ensuring sustainability the basin management approach aims at enhanced functioning of river basins, which should be reflected in a sound relation between people, water, land, fauna, flora and the basin’s ecosystem. The approach encourages participation in decision making processes concerning water resource management in the basin and thereto actively supports the decentralization of management functions to Basin Management Committees. It is believed that engaging stakeholders at increasingly lower levels of government can be relevant in situations where the supply of water is limited and where there is high competition for scarce resources, in order to negotiate equitable access to and sustainable use of the water resources. The following functions are devolved to the BMC (Seely et al. 2007):

- Identification of a basin water policy and strategy framework consistent with national policies
- Monitoring and reporting on health of the river basin
- Discussion of matters of concern on water use and management
- Identification and resolution of natural resource conflicts in basins
- Education of water users
- Development of a water research agenda
- Acquisition of technical support for water management institutions.

The basic concept and rationale of the basin management approach and the functions devolved to BMCs potentially provide scope for addressing vulnerabilities to climate change and for developing community based adaptation strategies with stakeholders on the committees. Before concluding as such, it should however be borne in mind that the experiences in Namibia and Southern Africa with Basin Management are of recent years and fairly modest as far as Namibia is concerned, where BMCs have been established in 4 of 11 basins only. In terms of water management issues the BMCs amongst others deal with the following matters, which often do not only relate to management of water resources, but to poverty concerns as well (Seely et al. 2007):

- Vandalism and damage to water infrastructure,
- Supply of water to new mining initiatives
- Dealing with the impact of floods
- Flood water harvesting
- Human – wildlife conflicts over water
- Distance to water points
- Affordability of water
- Access to safe water during the rainy season and pollution
- Fishing at the wrong time

Although climate change has major impacts on water resources, the list above underlines that the issue is not necessarily on the agenda of BMCs. Rather, committee members are interested in issues of poverty, the provision of more water. Similarly, some committee members are not interested in cost recovery as a measure to enhance the efficient use of scarce water resources (Kinyaga, personal communication). This underscores that climate change is not easy to translate to stakeholders on BMCs, and/or that stakeholders on BMCs are primarily faced with other concerns or lack knowledge and information to understand the implications of climate change for their livelihoods. Poverty therefore limits the capacity to adept to changing environmental conditions and makes people focus their energy on other matters of concern, rather than on changes that may affect them in the distant future.

Apart from poverty, basin management faces a number of more practical constraints. First of all the Water Act is not in full force yet, which limits the operations of BMCs. There generally is some lack of stakeholder feedback concerning issues on the agenda of BMCs and not all stakeholders participate regularly and consistently. It further appears difficult to provide feedback about matters dealt with by the BMC towards the wider community. Although institutional stakeholders are part of the BMCs, knowledge gaps and limited capacity hamper the operations of BMCs (Seely et al. 2007; Heyns, personal communication). In practical terms this implies that institutional stakeholders have to undertake the duties of the BMC on top of their daily work. Participation by community representatives is also influenced by the availability of resources for transport. The consequence of this is that more complex functions of the committees, such as developing management plans for basins, have not evolved as far as was hoped for. All of the above may be related to the fact that limited resources have so far been allocated to support the full functioning of BMCs, leading to a situation that Basin Management Committees encounter difficulties operating without the resources of donors or NGOs (Kinyaga, personal communication).

What has changed due to the basin management approach however is that institutions and communities are exchanging information concerning water resource management. As a result communities have better access to information, can voice their concerns and can contribute to the identification of problems, planning and decision making (Seely et al. 2007).
Based on the above one could conclude that BMCs could play a relatively strong role in the field of information exchange between institutional stakeholders and communities and could also serve the purpose of educating communities and the wider public in efficient water use. Information and education on how climate change is expected to affect communities in basins, may also be a function that BMCs can commit to. Given the observed capacity and resource constraints it would be rather far to expect BMCs to fully understand the ins and outs of climate change impacts on water resources in their basins and to plan accordingly. The latter would require additional resources, capacity building and testing of the approach.

5.6 Disaster risk management

With the increase in temperatures predicted for the whole of Namibia and in view of the observed shortening of the rainy season, drought events may occur more frequently in the future in Namibia. The predicted increase in late summer convective rainfall over Namibia means that larger amounts of rainfall can be expected in a shorter period late in the rainy season. This might have implications for the frequency of floods in northern regions, especially if it were coupled with similar increases in late summer rainfall over Angola and Zambia. At this stage the latter is not clear however; in fact a 10-20% decrease in annual rainfall is predicted for Zambia and Angola (as explained in section 3.4).

The following initiatives are relevant in managing disaster risks and are each discussed in sub-sections:

- Disaster risk preparedness and contingency planning
- Seasonal forecasting and flood forecasting
- Capacity building in spatial planning
- Disaster insurance for the poor

5.6.1 Disaster risk preparedness and contingency planning

In Namibia the Directorate of Emergency Management (DEM) at the Office of the Prime Minister (OPM) and Regional Emergency Management Units (REMUs) are responsible for disaster risk management. In line with the Decentralisation policy the intention of the National Drought Policy was to establish emergency management structures at constituency and village levels. Although REMUs engage with traditional leaders in their regions to respond to droughts and floods, these structures at constituency and village levels are in reality not in actually in place. Disaster risk management is further characterized by a focus on response in case of drought or flood, rather than on preparedness and risk reduction.

In this regard it is noteworthy that UNDP Namibia has taken the initiative to enhance the capacity of disaster risk management at national and regional levels by focusing on preparedness, contingency planning and risk reduction in collaboration with the OPM.

Thereto UNDP and OPM initially focus attention on 3 regions, with the aim to replicate lessons learned to other regions. UNDP support activities turn around capacity building at the regional government level (i.e. rural development planners) and the National Vulnerability Assessment Committee (VAC), including aspects such as vulnerability and risk mapping and improving information and communication between formal structures at national and regional level and communities. The latter serves the purpose of bringing formal or scientific intervention measures together with the traditional coping mechanisms of local communities. The latter is relevant as some indigenous practices, such as temporary migration to higher levels of elevation, seem to be have become weaker with increased infrastructure development in the flood plains. Although engaging the target group in vulnerability mapping can be very relevant to obtain a better understanding of local needs, coping mechanisms and options to address disasters, it is also relevant that a ‘physical’ record of the extent of disasters is obtained in years with extreme events. Given the extent of current floods in northern regions it is for example important to apply remote sensing techniques to establish where the floodwaters reach, so that this can be taken into consideration in infrastructure, town and settlement development.

To improve communication between the regional and national level UNDP suggests that regional representatives attend the VAC on a case by case basis. Furthermore media training is envisaged to improve the understanding of disaster risk reduction and the role the media can play in this regard. A matter that needs attention is the fact that impact of climate change on vulnerability to drought and floods is at this stage not mainstreamed in capacity building initiatives (Andrews 2008).

The approach suggested by UNDP Namibia seems to be in line with experiences of the AIACC project, which demonstrate that involving persons at risk in the process of adaptation can increase the effectiveness of adaptation to climate change, as in enhances the potential for focusing attention on risks that are priorities to the vulnerable. It further provides opportunities to learn from risk management practices currently in use and to identify opportunities and obstacles that are relevant and credible to vulnerable groups (Leary et al. 2007). Such an approach however implies that adequate resources be made available for research and capacity strengthening of community based adaptation practices.

5.6.2 Seasonal forecasting and flood forecasting

In a drought prone country like Namibia the number of weather stations that can be used for climate modelling and seasonal forecasting is rather small. In terms of disaster risk preparedness, capacity for early warning of both floods and droughts therefore needs to be expanded. The Meteorological Service plays a key role in the collection and processing of data from weather stations across the country, but the number of stations with long-term records has dropped since Independence and the number of staff that is responsible for managing the data is fairly small. The hydrology division at the MAWF plays a key role in flood forecasting, but also has a small staff establishment. To ensure continued monitoring and data processing during the rainy season, as well as effective communication of the resulting warning messages to stakeholders at regional level, including regional and local authorities that are members of the REMUs, extra resources would be required. These resources would be required to ensure that more weather and runoff data are collected and that the data are used for early warning systems. (Pegram et al. 2007) underscore that the end-users of information of early warning systems, such as the flood nowcasting system in South Africa, need to be properly trained in interpretation of the information generated. In addition adequate attention needs to be paid to procedures for communicating warnings to managers of disasters at other levels of government, i.e. the REMUs in Namibia.

5.6.3 Capacity building in spatial planning

Flood risk reduction could further be greatly enhanced by including specific attention for vulnerability to floods in regional and town planning processes. Infrastructure development since Independence in the flood plains in the Caprivi suggests that there is a dire need in this regard. The recent floods in the Cuvelai delta around urban areas such as Oshakati, Ondangwa, Outapi and Oshikango provide evidence for this need. The extent of flooding appears to have been influenced by infrastructure development that did not sufficiently take environmental conditions into consideration. The establishment of informal settlements in the oshana's – at times with support of government in the form of water reticulation systems-, as well as the construction of shopping malls, SME parks and other industrial zones in oshana's underline this point. This implies that vulnerability mapping should become an aspect of training of town and urban planners at tertiary education institutions, and possibly that specific efforts should be undertaken in terms of awareness raising and capacity building of the current establishment of town and regional planners, as well as engineers responsible for infrastructure development. Such capacity building efforts should comprise training elements on how the natural flow patterns of rivers can be sustained, with the aim of reducing flood related damage to infrastructure. A second reason is related to the need to ensure that the ecological requirements of animals and plants living along ephemeral rivers can be met. These ecosystems can usually quickly recover from dry spells, as long there is sufficient recharge when wet conditions return. But when dams permanently reduce flows and lower groundwater levels, these ecosystems are at risk of being permanently threatened. If this is further exacerbated by population pressure and concomitant over-exploitation of woods and plants in dry times, the food, shelter and water provided by rivers and flood plains, as well as ecosystem services such as flood attenuation, are permanently reduced.

Another reason for building capacity in spatial planning and engineering is related to the growth of the Namibian population and the vulnerability of livelihoods in rural areas. These factors will most likely contribute to higher rates of rural-urban migration and urbanisation. In view of these anticipated developments, it is important that more attention is given to planning for environmental health in (semi-)urban settings, including issues such as waste disposal, sanitation and sewerage.

5.6.4 Disaster insurance for the poor

Namibia currently experiences floods in the Cuvelai delta and Caprivi. In recent years floods (2003) and droughts (2003 and 2004) were experienced (Office of the Prime Minister 2003; Office of the Prime Minister 2004). These recent events merely underscore the high variability of the climate in Namibia and the vulnerability of the population in the northern regions to shocks of this nature.

Although GRN provides a safety net in the form of drought relief, it is generally acknowledged that natural disasters tend to have major impacts on the financial and productive resources of those affected, especially for subsistence oriented farmers. It is not only difficult for this category of farmers to protect themselves against the impact of floods and droughts, it can be even more difficult to recover from these climate related shocks, because the productive assets are often depleted during natural disasters. This fact is somehow underscored by data in chapter 2 which reveal that a significant proportion of the rural population hardly has access to productive resources.

Against this background it becomes more and more important to explore opportunities for disaster insurance for the poor by means of micro-insurance schemes, rather than merely organising post-disaster relief. The time seems to be right for such initiatives as donor agencies including the World Bank and Red Cross, development organisations and insurance companies (e.g. Munich Re) are interested in this topic (Churchill et al. 2006; Mechler et al. 2006).

Most experiences with disaster insurance for the poor are not older than 10-15 years. As such modalities are still in development; distinctions can so far be made between community-run initiatives, mutualities, direct sales schemes run by insurance companies and partner-agent models. The latter consist of a partnership between insurance companies and development organisations interested in micro-finance. Whilst experiences with the various approaches differ from country to country, the World Bank seems to advocate the mutuality as an approach “by” the poor rather than for other types of initiatives “for” the poor. Direct sales initiatives in certain countries however can be quite successful as some positive experiences in India (Tata – AIG) and Bangladesh (Delta Life) have shown (Churchill et al. 2006).

Such international experiences could be of interest to stakeholders in Namibia, as they could be linked to current national initiatives to further explore the potential for disaster insurance for Namibia’s poor. In this regard one could possibly build on experiences with savings and credit schemes supported by the Namibia Youth Credit Initiative (NYCI) of the Ministry of Youth, National Service, Sports and Culture (MYNSSC). In addition to the NYCI supported savings and credit schemes, RISE (an active partner of GRN in NYCI) has partnered with Alexander & Forbes to offer the possibility of household-wide funeral cover to Namibia’s rural poor for a premium of approximately N$25 per month (Gaomab, personal communication). Once this pilot has been evaluated it would be interesting to see whether this initiative could be expanded to cover natural disasters.

A third initiative that might be worthwhile learning from is a pilot of IRDNC and MET in the Kunene and Caprivi regions with providing inhabitants of conservancies with insurance cover against human-wildlife conflict. This initiative was developed because the CBNRM-program in the two regions contributed to an increase in the game population, but at the same time exacerbated conflicts with wildlife, mostly to the detriment of individual farmers. According to IRDNC the initiative is strictly seen neither a compensation programme nor insurance (no premiums are paid by participants), but a mechanism to more equitably distribute the income generated by conservancies, with the members that suffer most from living with wildlife getting a greater direct share of the benefits to cover this (Owen-Smith 2008). As it is the only form of ‘insurance’ for the rural population against natural events, known so far in Namibia, it may be worthwhile to consider aspects of this initiative that would have potential in terms of developing a broader insurance package that could address insurance against other natural disaster events.

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ANNEX A: Report on rainfall-runoff modelling in the Fish River Basin