NAMIBIA'S COUNTRY STUDY ON CLIMATE CHANGE

An overview of Namibia's Vulnerability to Climate Change
ERRATA

The following typographical errors have been noted:-

Page xix
ENERGY. Paragraph 3, Line 4. Should read ...which is currently responsible for 39% of Namibia’s electricity consumption.

Page 30
Table 4.1. Row 7, Column 2. Should read ....Increased electricity demand (mainly air conditioning and other coolants).

Page 71
Footnote 6. Line 3... man-induced changes to the Walvis Bay lagoon (Section 9.3.1) are believed to be ...

Page 145
Box 11.1.Paragraph 4, Line 1. Should read ....The capital cost of supplying 20 000 households ....

Footnote 5. Should read 90% of Namibia’s 20 000 rural households not connected to the grid ....
"There is evidence that the global economy is outgrowing the earth's ecosystems. We see this in the collapse of fisheries, in falling water tables on every continent, in rivers running dry and failing to reach the sea. We need to do two things in order to create a sustainable future: stabilise the population and stabilise the climate."

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PLEASE NOTE

- Unless otherwise stated, all prices in this document are current prices i.e. for the year quoted.
- All figures and tables that are unreferenced have been created/compiled by the author and should be quoted as such.

As a signatory to the UNFCCC, Namibia is required to complete a report on the country’s vulnerability to the potential effects of climate change. This document is an initial step in that direction. It is essentially a desktop survey, which attempts to consolidate current information, thus providing background material for future in-depth climate change impact and adaptation studies.

Written and illustrated for the DRFN by Jacque Tarr, November 1998.

Cover design by Asser Karita.
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List of abbreviations, acronyms and terms used in this document

BENEFIT - The Benguela Environment Fisheries Interaction and Training Programme
CAWMP - Central Areas Water Management Plan.
CBNRM - Community Based Natural Resource Management
CBPP - Contagious Bovine Pleuropneumonia
CCC - Canadian Climate Centre
CFC - chlorofluorocarbon
CSIR - Council for Scientific and Industrial Research (Republic of South Africa)
DEA - Directorate of Environmental Affairs
DF - Directorate of Forestry
DRFN - Desert Research Foundation of Namibia
DVS - Directorate of Veterinary Services, MAWRD.
DWA - Department of Water Affairs
EEAN - Environmental Evaluation Associates of Namibia
EEZ - Exclusive Economic Zone
EIA - Environmental Impact Assessment
EMA - Environmental Management Act
ENSO - El Niño Southern Oscillation phenomenon.
ENWC - Eastern National Water Carrier.
EPHD - Epidemiology and Public Health Division of the MHSS.
EPZ - Economic Processing Zone
GCM - General Circulation Model
GDP - Gross Domestic Product
GHG - Greenhouse Gases
GIS - Geographic Information System
GRN - Government of the Republic of Namibia
GTZ - Deutsche Gesellschaft für Technische Zusammenarbeit.
IBAs - Important Bird Areas
ICC - Inter-departmental Co-ordinating Committee [for global environmental change in South Africa]
ICZM - Integrated Coastal Zone Management
ICZMP - Integrated Coastal Zone Management Plan
IGBP - International Geosphere-Biosphere Programme
IIASA - Institute for Applied Systems Analysis (Austria)
IMR - Infant Mortality Rate
IPCC - Intergovernmental Panel on Climate Change.
IR radiation - infrared (long wavelength) radiation
MARA project - Mapping Malaria Risk in Africa project
MARENPRO - Namibia-German Marine Environmental Monitoring Project
MAWRD - Ministry of Agriculture, Water and Rural Development
MET - Ministry of Environment and Tourism
MFMR - Ministry of Fisheries and Marine Resources
MHSS - Ministry of Health and Social Services
MHWS - mean high water spring (tide mark)
MLRR - Ministry of Lands, Resettlement and Rehabilitation
Mm³ - millions of cubic metres
MME - Ministry of Mines and Energy
MoL - Ministry of Labour
MWTC - Ministry of Works, Transport and Communication
NAMDEB - The partnership formed between the Government of Namibia and De Beers. This company owns the sole mineral rights to prospect for diamonds in the Sperrgebiet (Diamond Area 1).
Nampor - Namibian Port Authority
NAPCOD - Namibia's Programme to Combat Desertification
NBRI - Namibia's Botanical Research Institute
NCAs - northern communal areas
NDP 1 - First National Development Plan (for the period 1995-2000)
NDTF - National Drought Task Force.
NDVI - Normalised Difference Vegetation Image
NEMC – National Emergency Management Committee
NEPRU – Namibian Economic and Policy Research Unit
NEWFIS – Namibia Early Warning & Food Information System
NMS – Namibia Meteorological Services
NNBTTF – Namibia’s National Biodiversity Task Force
NNF - Namibia Nature Foundation
NOAA – National Oceanic and Atmospheric Administration (USA)
NPC – National Planning Commission.
NRA – Natural Resource Accounts
OECD – Organisation for Economic Co-operation and Development
OSU – Oregon State University
PE – Potential evaporation
PET – Potential evapotranspiration
Ramsar site – A wetland of recognised international importance, (under the Ramsar Convention) especially as a waterfowl habitat.
SADC – Southern African Development Community which consists of the following 13 country members: Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.
SADC/ELMS – The Southern African Development Community’s Environment and Land Management Sector
SARDEP – Sustainable Animal and Range Development Programme
SEAFO – South East Atlantic Fisheries Organisation.
Sperrgebiet – The highly protected diamond area in southern Namibia.
SST – sea surface temperature
TAC – Total Allowable Catch
UKTR – United Kingdom Meteorological Office transient climate change experiment.
UNDP – United Nations Development Programme
UNFCCC – United Nations Framework Convention on Climate Change
Veldkos – edible wild plants
WASP – Water and Sanitation Policy
WHO/CTD – World Health Organisation, Division of Control of Tropical Diseases.
WMO – World Meteorological Organisation
WRI – World Resources Institute
WRSI – water requirement satisfaction index
WTO – World Trade Organisation
EXTENDED SUMMARY

INTRODUCTION
Since the onset of the industrial revolution, raised concentrations of atmospheric greenhouse gases (mainly carbon dioxide, methane and nitrous oxide), resulting from the burning of fossil fuels and other human activities, have begun to cause a discernible increase in the earth’s average surface temperature. In turn, this has triggered an increase in average global sea-level and is believed to have initiated certain large scale, long term changes to global climate, including increases in sea surface temperatures and changes in rainfall, flood and drought regimes. Collectively, these changes are referred to as global warming, the enhanced greenhouse effect or climate change.

Namibia, as a developing country located in an arid region where drought and high climatic variability is endemic, and where great demands are placed upon natural resources, is considered to be particularly sensitive to the effects of climate change. Vulnerability to global warming is a measure of the country’s capacity to cope with the expected impacts and will largely be determined by the population growth rate, future economic growth rate, natural resource base status, rates of land conversion/degradation, domestic and regional stability and national policies and practices. By offering an overview of these interactive factors, this document identifies Namibia’s most climate sensitive sectors. Furthermore, it aims to create awareness concerning national vulnerability to climate change and lay a foundation for future in-depth multisectoral impact studies.

CURRENT CLIMATE
Namibia experiences precipitation from only the edges of the southern African rain-bearing systems. As a result, the country’s climate is characterised by aridity and variability with 92% of the land area defined as hyper-arid, arid or semi-arid. During the last 5-10 million years desert conditions along the country’s naturally arid coastline have been enhanced by the presence of the cold Benguela current. Along the coastal belt, precipitation from advective fog exceeds precipitation from rainfall and plays an important role in the ecological functioning of the Namib Desert. Rainfall variability within the region is closely associated with anomalies in sea surface temperature resulting from the El Niño/Southern Oscillation phenomenon and other causes. Droughts are common and below average rainfall often occurs for periods longer than 2 years.

Namibia’s predominantly southerly and south-westerly coastal wind regime has a profound effect on the marine ecosystem and generally results in cool temperatures at the coast. On average, maximum temperatures across the country vary between 3 °C and 40 °C. The hottest time along the coastal belt is often during autumn or winter when easterly winds may occur for short periods. On average, minimum temperatures across the country vary from 2 °C to 10 °C but may reach as low as −10 °C at some inland localities. Namibia’s interior plateau is characterised by an extremely high evaporation rate that exceeds average rainfall.
FUTURE CLIMATE
Our estimation of future climate changes resulting from the enhanced greenhouse effect must take into account the fact that large scale, naturally induced changes to global climate have occurred in the past, and will occur again in the future.

Based on the IPCC IS92a Greenhouse Gas Emissions Scenario, which offers a mid-range estimate of future greenhouse gas emissions and assumes only a modest degree of policy intervention to mitigate them, climate models estimate that the mean annual global surface temperature will increase by 1.5 – 4.5 °C by 2100 (compared with 1990). Increased temperatures are expected to be greatest at the poles, the northern hemisphere is expected to warm more than the southern hemisphere, winter warming is likely to be greater than summer warming and diurnal minimum temperatures are hypothesised to increase more than maximum temperatures. Changes in spatial and temporal patterns of precipitation are also expected, but the exact nature of these changes is difficult to determine. ENSO conditions are likely to intensify and naturally dry areas in southern Africa are expected to become drier during El Niño events.

Of the many interactive atmospheric/oceanic effects and feedback responses that are anticipated as a result of global warming, a rise in sea-level and enhanced sea surface temperatures will be the most discernible. The IS92a greenhouse gas scenario estimates a sea-level rise of between 23– 96 cm by 2100. Sea surface temperatures are expected to rise with an increase in air temperature, but neither to the same degree nor as rapidly.

Although it is not possible to predict with any degree of certainty the exact timing, magnitude and nature of expected climate changes under the effects of global warming, recently developed scenarios suggest that, in addition to becoming increasingly hotter, most of the SADC region is likely to become drier and will experience shorter, less reliable rainy seasons during forthcoming decades. Based on a regional study conducted by Hulme et al., one climate change scenario for the SADC region (Hulme’s ‘core’ scenario) suggests average warming of approximately 1.7 °C, decreased rainfall of between 2.5-7.5%, increased rainfall variability of between 5 and 15% and increases in potential evapotranspiration of between 4 and 16% for most of Namibia by the 2050s decade.

Some environmentalists maintain that southern Africa is already experiencing the consequences of an enhanced greenhouse effect - average temperatures in the region have risen by 0.5 °C during the past century and the 1986-1995 decade has been the warmest and driest since 1900. Furthermore, El Niño events appear to be more frequent and intense, often heralding periods of drought. Mean temperatures for Windhoek during the last five decades have displayed an average increase of 0.023 °C/annum and, since the 1970s, Namibia’s volumetric rainfall has steadily declined.

Although it is not possible to prove that these drier and hotter conditions are a result of global warming, it is quite clear that decision-makers must begin to plan in the face of considerable climatic uncertainty. Thus, there is a strong need for Namibia’s meteorological services to improve existing databases and to become increasingly proactive regarding the distribution of relevant climatic information. The potential for understanding world-wide weather teleconnections such as the global consequences of
ENSO events is improving constantly and much can be learnt from national responses to these events.

Although the broadbrush regional scenarios used in this document provide a valuable backdrop for this preliminary study, national in-depth climate change impact studies will require the generation of future climate scenarios that are specific to Namibia. Work in this field has begun and it is important that it continues.

**SOCIO-ECONOMIC SCENARIOS**

Namibia supports an expanding, youthful population and displays rapid rates of urban growth. The economy relies heavily on natural resources and agriculture remains the principle source of employment and livelihood for the majority of the population. Scarcity of water and episodic drought limit economic development and the economy is neither sufficiently diverse nor flexible enough to cushion it against the fluctuating international and environmental conditions that affect the mining, marine fishery and agricultural sectors.

As part of its colonial legacy, Namibia has a highly dualistic economy and the top 1% earners are estimated to have a total annual income that exceeds the total income of the bottom 50%. In 1994, approximately 60% of the population were classified as either poor or severely poor. Unemployment and underemployment is high and few formal sector jobs are found in the heavily populated northern regions of the country.

Fishing and fish processing are expected to display strong growth in the immediate future but this will depend on the recovery of fish stocks and conducive environmental conditions. Tourism is expected to continue to grow and the development of the Kudu gas field and the proposed new hydroelectric power scheme on the Kunene river will result in substantial increases in future electricity output. Although not likely to show any dramatic growth by 2000, it is hoped that manufacturing will flourish in decades to come, thus providing off-farm employment opportunities and creating a more diverse economy. The impact of HIV/AIDS on population growth rates is uncertain but it is likely that the epidemic will place tremendous strain on Namibia’s future economy, due mainly to increased demands on health and social services and illness/mortalities amongst the economically active sector of society.

**SOCIO-ECONOMIC IMPACTS OF CLIMATE CHANGE**

Increased urbanisation, increased health care and water supply costs, disease epidemics, and a reduction in food security, exports, employment and tourism potential, are all possible socio-economic consequences of global warming. The most vulnerable sectors of society are considered to be the urban poor residing in rapidly growing, inadequately serviced informal areas, and rural communities dependent on subsistence farming for their livelihoods.

Since independence there has been a commendable improvement in policies and programmes that aim to achieve sustainable natural resource management in Namibia. In addition, an IIASA project on Population and Sustainable Development in Namibia will help to guide future national and regional economic planning and will provide valuable information for future climate change studies. However, improved conditions in informal
urban areas and concerted efforts to reduce population growth rates, poverty, the spread of HIV/AIDS, and advance economic flexibility and growth, are essential to mitigate the effects of climate change and help to ensure that Namibia is able to pursue costly adaptation measures.

VULNERABLE SECTORS

WATER RESOURCES
Rainfall in Namibia is sparse and displays a high degree of temporal and spatial variability. This leads to a corresponding high variability in runoff, soil moisture and stream flow. Because of high evaporation rates, only 2% of the rain that falls is available as runoff and only 1% is available to recharge groundwater. This scarcity of water limits the development of virtually all sectors in Namibia.

Until recently, water supply was heavily subsidised and the government focussed on trying to provide enough water to meet demand. This approach has encouraged the wasteful use of water, led to misguided agricultural policies and the establishment of inappropriate irrigation schemes. If demand continues to grow at current rates of 3.5% per annum, then water consumption will double every 20 years and by 2015 Namibia will no longer be self-sufficient in water. Major constraints, which currently challenge national and regional water resources, irrespective of climate change, may be summarised as follows:

- Escalating financial costs of supplying adequate water to agriculture (mainly crop irrigation), industry, commerce and an expanding, urbanising population;
- Increasing concentrations of pollution which threaten the quality of diminishing water supplies;
- Increasing water scarcity and competition with neighbouring countries for available water; and
- Environmental damage resulting from the unsustainable removal of water from underground aquifers. In particular, damage to riparian vegetation and wetland ecosystems which provide essential ecological services including water purification, streamflow regulation and the recycling of aquatic nutrients.

In order to cope with increasing national water demand, it has become essential to enforce stricter water management policies together with investigating the possibility of developing new water sources. Attempts to ensure full cost pricing for water resources are likely to reduce future demand in sectors that display a very low economic return on water input (irrigated crop farming and domestic use) but not with others (mining, fish processing, and tourism) that generate relatively high returns.

By the 2050s the water resources sector is likely to be affected by increased temperatures, a decrease in precipitation in most areas, altered runoff (reduced by 10-40% for most of the country) and increased runoff variability as a result of climate change. More extreme flood events during years of good rain are also likely. Reduced water quality and availability will severely exacerbate all current constraints that challenge the water resources sector and will ultimately result in increased threats to public health, increased variability in hydropower output and reduced production from some industries. A
reduction in rainfall will result in exponentially less runoff and a reduction in dam yield that will be also be subjected to an increase in evaporation. Current constraints that threaten the fresh water fisheries sector will be perturbed. Collectively these impacts will severely threaten Namibia’s socio-economic and environmental integrity.

Recent changes in water management policy, particularly those relating to more realistic water pricing and efforts to co-ordinate planning and management at a regional level, will have considerable net benefits for the water resource sector. Nevertheless, the likely costs and effects of climate change still need to be considered by water managers and factored into all future macroeconomic planning processes. Thus, a quantitative assessment of the biophysical and socio-economic impacts of global warming on Namibia’s water resources should form the focal point of future climate change impact studies.

MARINE RESOURCES
Namibia’s marine ecosystem is characterised by intense upwellings, which are dependent on prevailing southwesterly winds and the northward flowing Benguela current. Although species diversity of the Benguela ecosystem is low, the ecosystem’s cold, nutrient rich upwelled waters support large quantities of plankton, which in turn sustain vast populations of commercially exploitable fish and other marine organisms.

Reds tides, sulphur eruptions, deep water anoxia and episodic warm water events or Benguela Niños, are extreme natural events that periodically impact upon Namibia’s marine environment. These unpredictable phenomena are largely triggered by climatic factors (particularly changes to the prevailing south-westerly wind regime) and are capable of having a dramatic effect on fish stocks. In addition to the natural climatic variability that drive these changes, threats to the production of Namibia’s marine fisheries sector include the over exploitation of stocks and increasing inshore pollution.

In the early 1990’s, favorable environmental conditions, the establishment of an exclusive economic zone (EEZ) and the setting of conservative total allowable catches (TAC’s) have helped fish stocks to recover after decades of overexploitation. There is a growing trend in global fish consumption and, despite the unpredictable variability displayed by Namibia’s marine environment, there is national optimism regarding future earnings from this sector.

Of the many interlinked atmospheric and oceanic changes that will affect marine environments as a result of global warming, only an increase in sea surface temperature (SST) and a rise in sea-level are predicted with any degree of confidence. Increased SST alone will be capable of shifting wind and pressure regimes, altering the ocean’s primary production and impacting on the distribution and population dynamics of many marine species. However, researchers can only hypothesize how the interactive winds, ocean currents and upwelling processes that fuel the Benguela’s high productivity may change under altered climatic conditions.

Initially, climate change may not create new problems for Namibia’s marine fisheries sector as much as it exacerbates existing ones. Thus, the environmental conditions that prevail during the occurrence of Benguela Niños and other anomalous events may
become more prevalent in the short to medium term. After about 2050 however, permanent changes to the Benguela upwelling could result, with many fish species migrating out of Namibian waters, to be replaced by more diverse assemblages adapted to warmer conditions. Although biodiversity is likely to be enhanced under these circumstances, the production of the Benguela will ultimately diminish. If this extreme scenario does develop, it will have a severely detrimental effect on Namibia’s marine fisheries sector.

It is hypothesized with medium confidence that climate change conditions will not cause significant changes to global marine fisheries production as a whole. Rather, there will be a shift in economic winners and losers in accordance with the expected geographical displacement of fish stocks.

Marine species most sensitive to climate change include those that have been heavily exploited. Thus, in order to help mitigate future vulnerability, it is essential to ensure that current local, regional and global policies provide for stock recovery and enforce sustainable fishing practices. At a local level, policies that favor fish processing over larger catches and programs that encourage the improvement of existing models for forecasting marine environmental changes associated with the Benguela current ecosystem are strongly recommended.

**AGRICULTURE**

Despite considerable climatic constraints, 85% of Namibia’s land surface is used for agricultural purposes. More than 90% of this land is utilised for livestock farming as a lack of precipitation restricts crop farming to limited areas in the north of the country. Approximately 48% of the actual Namibian labour force is employed by the agricultural sector, with an estimated 70% of the population dependent either directly or indirectly on agriculture for its livelihood.

The colonial era created two agricultural sub-sectors - communal and commercial. Agricultural incomes for subsistence farmers on communal land are low and variable and are dependent on rainfed crops (mainly millet) and livestock which supply families with many non-marketed products and services including draught power, milk, hides and manure. Commercial farms are large and mainly oriented towards meat production for local and export markets.

Extended periods of drought impact heavily on Namibia’s agricultural sector and the tenuous food security of the rural poor. During the 1990s livestock losses were predominantly due to the effects of drought. In recent years, commercial livestock farmers have moved increasingly towards mixed game/livestock farming and many have embarked upon wildlife based tourism enterprises. This trend in stock diversification has helped to maintain biodiversity and creates a valuable buffer against the effects of drought.

Poor soil, low and variable rainfall and high temperatures strongly limit the potential for sustainable agricultural practices and Namibian rangelands are vulnerable to land degradation. The causes of land degradation result from several interlinked climatic, social and political factors, which combine to threaten commercial agricultural output and
the livelihoods of rural communities. Thus, although regular drought and natural climate changes are capable of causing undesirable shifts in vegetation cover that predispose rangelands to soil erosion and bush encroachment, these effects are exacerbated by unsuitable agricultural practices, inappropriate policies and increasing population pressure.

Over the next 20 years, economic growth rates for the agricultural sector are not expected to rise much above 5% per annum. Determining the ultimate effects of climate change on these projections is hampered by many uncertainties. These include the future effects and extent of land degradation, the quantification of future rainfall variability, the actual response of plants (crops and rangeland grasses) to the combined effects of increased concentrations of CO₂ and elevated temperatures, the consequences of improved cultivation practices and altered social, economic and political circumstances. Nevertheless, assessments within the SADC region which have focussed on projected changes in potential yields of maize, as well as broad-brush investigations into some climate change effects on rangelands and livestock health, suggest the following possible consequences of global warming:

- **Geographical shifts in the areas suited to crop growth are highly probable.** Based on the influence of increased CO₂ and temperature alone, Namibia’s maize triangle and Caprivi region could experience an increase in maize yields of up to 5% under Hulme’s ‘core’ climate change scenario. However, if rainfall is reduced and becomes more variable, fewer areas will be suitable for cultivation.

- **The growing season of maize is likely to shift to an earlier date and, as a result of increased temperatures, shorter growing seasons and reduced yield quality are likely.** Altered prevalence of weeds and crop pests are also expected. A decline in surface water availability will be accompanied by fewer opportunities to develop irrigation schemes.

- **Reductions in forage quality and palatability are likely to occur because of increasing carbon to nitrogen ratios, particularly on Namibian rangelands where low nutritional value is already a problem.**

- **If a general trend towards increased aridification occurs in Namibia, desert expansion in semi-arid regions will reduce livestock carrying capacity.** Changes in vegetation cover will significantly increase rates of soil erosion, particularly in the absence of sustainable rangeland management practices.

- **Increased incidence of drought will have detrimental effects on livestock morbidity and mortality.** Livestock plant poisonings are an important cause of mortality throughout Namibia and appear to increase after prolonged dry spells. Altered geographical ranges of vector born diseases are expected. Under a general aridification scenario reduced risk of some livestock diseases could be accompanied by an increase in viability for livestock in the north eastern parts of the country.

Ultimately a future climatic regime that is hotter, drier and more variable will have severe consequences for local and regional food supply, land use options, production profitability, poverty, employment potential and economic sector competitiveness. As marginal conditions have prevailed in Namibia for several decades, the overall impacts of climate change under a general aridification scenario are likely to be less detrimental for the local commercial farming sector than in other parts of SADC. However, impacts on
household food security amongst subsistence farming communities could be dramatic. Consequently, studies on the vulnerability of subsistence crops in Namibia should form the focal point of future investigations into climate change impacts on the country’s food security. In addition, Namibia’s increasing dependency on food imports means that climate change impacts on the agricultural sector should be considered within a regional context.

Mitigating some of the expected effects of climate change on the agricultural sector requires sustainable and diversified economic development. Future irrigation schemes must be kept in perspective with Namibia’s hydrological reality and water and agricultural policy must be integrated. Furthermore, in order to enhance the responsiveness and adaptation of the agricultural sector to forecasts of production variations and food crises, improvements in monitoring and communication capabilities are essential.

**BIODIVERSITY AND ECOSYSTEMS**

Ecosystems that support a rich biological diversity and variety of trophic pathways display greater resilience to disease, pestilence and extreme environmental conditions. In addition to directly enhancing rural livelihoods and providing the Namibian economy with valuable resources, natural ecosystems and ecological processes recycle nutrients, facilitate ground water recharge and stabilise the soil. Thus, the maintenance of biodiversity and natural habitats is essential to human survival.

Namibia supports many unique habitats and accompanying plant and animal assemblages within the country’s three major terrestrial biomes viz. hyper-arid desert, which covers 16% of the total land area; arid to semi-arid savanna, which covers the central and north central plateau, comprising roughly 64 % of the land area; and dry sub-humid woodland which occurs in the wetter northeast. The higher wildlife biomass and species richness in the latter area is attributed to the presence of large, perennial tropical river systems. Species richness in almost all of the marine habitats is relatively low but, due to the nutrient rich upwelled waters that characterise the Benguela ecosystem, Namibia’s cold ocean supports one of the highest concentrations of sea life found anywhere in the world. Determining the current status of Namibia’s biota is difficult as only a small number (possibly as few as 20%) of local species have been described to date and, with the exception of most terrestrial vertebrate groups, there are still considerable gaps in knowledge regarding the taxonomy and biogeography of most taxa.

Many practices currently threaten the maintenance of local and regional biodiversity. These include the destruction of habitats (due mainly to land degradation and land clearing), a lack of pollution control, overexploitation of certain species, inadequate conservation measures outside protected areas, illegal trade and hunting and the invasion of alien species. Furthermore, national parks and reserves do not adequately protect Namibia’s biodiversity. Virtually all wetlands, and their accompanying fauna and flora, although identified as the country’s most threatened resources, are severely underprotected, as are many centers of floral and vertebrate endemism. In addition, Namibia has no proclaimed marine reserves.
In spite of this, many positive efforts to help secure Namibia’s future environmental health have been made. Moves to improve pollution control have begun and profitable wildlife based enterprises on commercial farmland have increased the amount of land allocated to wild populations. The formation of communal conservancies, through the CBNRM program, aims to distribute the benefits from sustainable wildlife use in communal areas to the local communities involved. Thus, the economic value of wildlife is expected to increase over the next 10 – 15 years and, consequently, some wildlife habitats and populations will continue to benefit.

Climate directly determines the nature and functioning of ecosystems. Although biomal shifts and a loss of terrestrial species are expected to occur in response to the higher temperatures that will accompany global warming, it is currently not possible to determine exact changes in trophic interactions within ecosystems nor shifts in their net primary production. This is due to many uncertainties, including the future effects of land degradation, the actual responses of plants to increased temperatures and concentrations of CO$_2$ and the degree and manner in which precipitation patterns will change. Nevertheless, based on “what if” scenarios, it can be hypothesised that:-

- The species most at risk under altered climatic conditions are likely to be those that are geographically localised, genetically impoverished, poor dispersers, slow reproducers or currently at the edge of their optimal tolerance levels.
- Under scenarios of increased aridification (elevated temperatures and declining rainfall) semi-arid areas in Namibia are likely to become arid and dry sub-tropical areas could shift to semi-arid conditions. Rates of land degradation are likely to increase under this scenario.
- Fast growing weeds and bush encroachment species, which commonly yield less timber, provide lower quality foliage for domestic and wild animals and supply poorer quality habitats are expected to benefit from global warming.
- Insects with their rapid life cycles and high fecundity are also likely to track changes in climate extremely effectively. As a result, increased bio-invasions of pests and disease carrying vectors are predicted.
- Based on increased temperatures and altered habitats, certain ungulate species could decline in Namibia’s arid highlands.
- Permanent damage to Namibia’s natural wetlands is likely to occur if the region becomes more arid under climate change conditions.
- The possibility of fewer fog days along the coast will threaten the survival of many unique, endemic plant and animal species that are well adapted to current conditions within the fog belt. Furthermore, increased temperatures, accompanied by reduced winter rainfall will threaten the rare succulent flora that characterises the Sperrgebiet.

In response to the many potential interactive effects of global warming on Namibia’s marine environment, including increased SST and sea-level rise, the following possible outcomes can be hypothesised:-

- A reduction in the shore zone in a seaward direction and changes in tidal ranges;
- Increased sandy beach erosion and altered sedimentation of coastal lagoons;
- Sedentary species, which are restricted geographically by the limiting effects of temperature, will be most vulnerable to local extinction. The new, more tropical species assemblages that appear in Namibian waters are likely to display a higher
degree of biodiversity but the system as a whole will display lower production. This could ultimately have severe economic implications for Namibia’s pelagic fishing industry.

- Namibia’s offshore islands, important roosting and breeding sites for several species of sea and shorebirds, are likely to experience increased inundation and vulnerability to storm events.
- Negative effects on the feeding behaviour, population dynamics and ultimately, the biodiversity of many shorebirds are expected as a result of sea-level rise and increased desiccation of the littoral zone.
- Slackening of the south-westerly winds or prolonged periods of hot east wind will be detrimental to the local survival of Cape fur seal pups. In addition, all top predators of the Benguela system (fish, seabirds and mammals) will be affected by altered food supplies due to the changes in primary productivity that could accompany altered wind regimes, upwelling frequency and strength.

It is not possible to prevent the loss of species and biomass shifts that are likely to accompany changes in global climate. Although some plant and animal species may migrate fast enough to keep up with projected changes, they will only do so if they are able to move through continuous, relatively undisturbed natural ecosystems. Consequently, the degree to which current and future activities either alter, fragment, isolate or stress Namibia’s natural ecosystems, will ultimately determine the resilience of wild populations to future changes in atmospheric composition and climate within the region. Thus, mitigating the effects of climate change on local and regional wildlife populations and the water resources and habitats that support them, will require:

- A reduction in land degradation, land clearing and other activities that cause a loss of natural habitats and ultimately increase the sensitivity of ecosystems, particularly those in arid and semi arid areas, to drought and other extreme climatic events.
- The development of large, cross-boundary reserves which preferably incorporate entire functioning ecosystems, areas of high biodiversity and/or endemism, and span altitudinal, soil and climatic gradients.

Several areas of potential cross-border tourism and wildlife management between Namibia and her neighbours exist. These include parts of the Caprivzi where most wildlife herds migrate to and from Botswana, Zimbabwe, Zambia and Angola and south western Namibia where the Sperrgebiet and Ai-Ais/Huns Mountains could be linked to South Africa’s Richtersveld National park, the Skeleton Coast Park and the Iona National Park in Angola. If such parks are proclaimed, they will make significant contributions towards biodiversity and habitat conservation in the region, particularly under the threat of altered climatic conditions.

**COASTAL ZONES AND SYSTEMS**

It is estimated that global sea-level has risen by 1.0 - 2.5 mm/year during the past 100 years. Tide gauge records from Lüderitz and other localities on the west coast of southern Africa over the last 30 years revealed an estimated sea-level rise that is comparable with these global measurements. An acceleration of this rise as a consequence of global warming is predicted with high confidence and the IS92a greenhouse gas emissions scenario estimates a global sea-level rise, above those recorded in the mid-1990’s, of 6 - 25 cm by 2030, 10 - 65 cm by 2070 and 23 - 96 cm by 2100.
Depending on local geomorphological conditions any one, or a combination of, the following broad responses to sea-level rise are possible at a particular site: -

- Increased coastal erosion;
- Flooding, inundation and displacement of wetlands and lowlands;
- Impairment of water quality into freshwater aquifers and estuaries due to increased salt intrusion;
- Reduced protection from extreme storm and flood events.

Vulnerability is expected to increase dramatically in areas that have been modified or exploited by humans. Thus, any current environmental threats to ecological systems, human health, underground water resources, inshore marine industries, the tourism sector, coastal urban infrastructure and investment are likely to be compounded by sea-level rise.

Low rainfall and limited freshwater resources have restricted economic development along the Namibian coast. Nevertheless, the few coastal towns and settlements remain important centers for the country’s fishing, tourism, guano, salt and mariculture industries. Coastal wetlands, including the three Ramsar sites (Sandwich Harbour, Walvis Bay lagoon and Orange River mouth) provide nursery areas for some fish species and are important feeding grounds for large flocks of palaeartic and resident shorebirds. In addition, Namibia’s 13 small offshore islands offer safe breeding and roosting habitats for several seabird species. Current stresses on Namibia’s coastal zones and systems include rapid urbanisation, growing unemployment, housing shortages and a strain on health and waste management services in Lüderitz, Walvis Bay, Swakopmund, Henties Bay and increasing pollution of inshore waters in the vicinity of the Walvis Bay and Lüderitz harbours.

Walvis Bay is of strategic economic importance to Namibia and land locked countries within SADC. Current planning in the town includes expanding trade with neighbouring countries and the international world. In recent years, parts of the Walvis Bay lagoon, Namibia’s largest and most important coastal wetland, have been drained and converted into luxury suburbs, thus reducing its ability to adapt naturally to altered environmental conditions. In 1991 a preliminary study on the vulnerability of Walvis Bay ascertained that the town is likely to experience impacts of first order magnitude to the effects of sea-level rise. The main threats are likely to result from increased incidence of flooding and inundation of the low-lying areas of the town and increased vulnerability to the effects of higher storm-induced coastal water levels.

In order to identify feasible adaptation options and reduce potential losses to land, property, infrastructure and tourism/recreation potential, it is essential to conduct sea-level rise impact assessment investigations, similar to the preliminary Walvis Bay study, on all of Namibia’s rapidly growing coastal settlements and sites of ecological importance. The expected responses to sea-level rise need to be considered during all coastal zone planning processes preferably through Integrated Coastal Zone Management Plans (ICZMPs).
In order to reduce conflicts of interest in resource utilisation and ensure co-ordination between stakeholders, an ICZMP for the Erongo region has been initiated. Information gathered by the ICZMP team will be useful in helping to formulate policies for development and will provide a valuable foundation for any future detailed climate change vulnerability and adaptation studies along this part of the Namibian coast.

HEALTH

Human health is strongly linked to environmental health and is largely determined by access to clean water, adequate food and shelter. Infant and childhood mortality rates correlate well with the living conditions in a country and are often referred to as indicators of national health. The highest infant and under 5 year old deaths in Namibia occur amongst rural populations that are highly vulnerable to the effects of drought and were historically disadvantaged regarding access to adequate medical facilities, clean water and education. Diarrhoea, undernutrition, malaria and acute respiratory infections are the cause of most death in this age group, while AIDS, tuberculosis and malaria are identified as the main causes of all deaths reported in the country.

Despite considerable improvements in rural water supply and primary health care since 1990, there are still large disparities between urban and rural access to adequate services. Recent environmental health indicators for developing countries still rank Namibia as highly vulnerable to environmental impacts due to low national water and food security status. Circumstances in neighbouring Zambia and Angola are worse and cross border infiltration of communicable diseases pose a constant threat to vulnerable communities in Namibia.

Climate influences many of the key determinants of disease and multiple health impacts, including the unforeseeable emergence of new or resurgent diseases, are expected to result from global warming. Uncertainties regarding future climate scenarios, the response of pathogens and the vulnerability of future populations, makes it difficult to predict the exact impacts that will be vested on any region. However, heat related mortality, altered incidence of vector borne, water borne and water washed diseases, health problems relating to reduced nutritional status, increased incidence of toxic algal blooms and reduced resistance to disease as a result of threatened food security, disrupted water supply and increased pollen induced allergies and asthma, are all probable.

A spread in malaria and a reduction in habitat suitability of the African trypanosomiasis vector as a result of climate change are possible. Hulme’s ‘core’ climate change scenario for the SADC region suggests an expansion of malaria from the north and east into central Namibia during years of good rain. This shift in the disease may already be occurring as both the southern health directorate (particularly in the Gobabis district) and central health directorates have reported considerable increases in malaria incidence in recent years.

There is also the possibility that several diseases including lymphatic filariasis, dengue, yellow fever and cholera could infiltrate Namibia from neighbouring countries. An attempt should be made to determine the likely effects of climate change on the distribution of these diseases.
Increasing climatic variability is likely to occur over most of southern Africa and for some diseases this may be more important than changes in mean climate. In southern Africa, climatic variability is partly determined by the ENSO phenomenon. El Niño periods often herald severe drought within the region. Frequent droughts result in lowered resistance to disease and can cause alterations to the distribution of certain vector species. In addition, drought causes an increase in Vitamin A deficiency and incidence of waterborne and water washed diseases amongst poor communities.

Reducing the effects of climate change on Namibia’s health sector depend largely on:-

- Ensuring that the quality of life for both rural and marginilised urban communities continue to improve;
- Reducing environmental damage, improving food security;
- Improving disaster preparedness;
- Ensuring appropriate health care.

In recent years, commendable efforts have been made to improve the basic living conditions of Namibia’s rural population. However, many of the country’s burgeoning informal urban communities, in the absence of adequate services, are becoming increasingly susceptible to disease and the potential health risks posed by an altered climatic regime.

ENERGY

On average, Namibia spends 15% of GDP on energy. 78% of the total energy used in 1993 was supplied in the form of petroleum products, imported electricity and coal (for local thermal electric generation). Biomass fuel (mainly wood) comprised the remaining 22%.

Electricity output from the Ruacana hydroelectric power station varies seasonally with the flow of the Kunene River. Only a small percentage of the country’s electricity demand is produced by coal–fired thermal generation because of increases in the price of coal. Thus, in most years, Namibia imports a proportionately large amount of the nations electricity requirements from neighbouring countries.

Increases in domestic electricity demand have grown at an estimated rate of 4% per annum since 1990. Further increases in demand are expected due to population growth, urbanisation, water transfer and desalination schemes. However, these increases will be partly offset by low growth in the mining sector, which is currently responsible for 34% of Namibia’s electricity consumption.

As only 4% of rural households are connected to the electricity grid, one of the major challenges that faces the energy sector is the need to improve energy supply to the disadvantaged rural communities. However, as most rural households have a low purchasing power relative to commercial energy costs, imported energy is not considered to be economically viable for these areas. Thus, dependency on fuelwood for cooking and batteries and/or paraffin for lighting by Namibia’s rural majority is unlikely to abate during future decades, unless suitable cost effective substitutes can be supplied.
Although the development of the Kudu gas field, and the proposed hydroelectric dam on the Kunene River offer opportunities for Namibia to achieve self-sufficiency in electricity production, neither will be able to meet the needs of remote, dispersed populations without considerable extra expenditure. Solar energy is currently underutilised in Namibia but has tremendous potential for mitigating GHG emissions and meeting rural energy demand.

Climate change is likely to affect both energy production and energy consumption in Namibia. The extent of these effects is closely linked to economic development and will largely be determined by the country’s future dependency on woodfuel and electricity produced from hydropower. Output from the proposed Epupa dam will be strongly influenced by an altered rainfall regime in the catchment areas of the Kunene River and any future development projects upstream in Angola. If hydropower generation becomes severely hampered due to reduced rainfall, the use of solar power could gradually become an economic necessity in Namibia.

Total fuel wood availability may increase as a result of global warming as it has been hypothesised that the spread of bush encroachment species will be favoured under an altered climatic regime. Global warming could also cause a substantial increase in electricity consumption, mainly as a result of the increased use of cooling equipment. In Namibia the magnitude of this impact will depend on future economic development and improved standards of living.

In order to assess the full extent of the vulnerability of Namibia’s energy sector, specialist studies are required to determine how the flow of the Kunene river is expected to change in response to altered rainfall patterns. Increased demands from Angolan users need to be considered too. Estimates of future biomass availability under climate change scenarios also need to be developed and compared with projected future demand.

Ultimately, Namibia needs to diversify into alternative energy sources and develop flexibility within the energy sector. This will enhance resilience and adaptability in the face of unpredictable, changing environmental conditions.

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**FINAL CONCLUSIONS AND RECOMMENDATIONS**

Namibia is extremely sensitive to global warming and, due to human resource, institutional and financial constraints, is considered highly vulnerable to the effects of climate change. The direct impacts of global warming on each of the economic sectors reviewed in this document have the potential to create ripple effects on each other, ultimately reducing productivity, sustainable development options and social stability. If, as currently suggested by some regional scenarios, the country’s climate continues to become hotter, drier and more variable (with the exception of Caprivi, where it may become wetter), it is clear that marginalised rural and urban populations will suffer the most.
Significant links and overlaps occur between the effects of climate change, biodiversity loss, ozone depletion and desertification. Thus, national and international action must be integrated and co-ordinated to avoid the duplication of programmes and activities.

Bearing in mind these considerations, the working group on Vulnerability to Climate Change from the Final Workshop for Namibia’s Initial Climate Change Report held in Windhoek (February 10th 1999) recommended the following:

1. Future research
   - The creation of plausible baseline scenarios necessary for future sectoral vulnerability studies will be able to draw on information from the Natural Resource Accounting Programme, the National Biodiversity Programme, Namibia’s State of Environment Reports, NetWise and other ongoing projects. Nevertheless there is a strong need for the development of human resources and the continual creation of reliable databases on climate, soils, vegetation and fauna. All efforts to develop such databases and networks must continue.

   - Ongoing climate modelling, specific to Namibia, is essential for all forthcoming research. There is an urgent need to build up capacity, systems of information exchange and co-operative research within the region regarding this highly specialised aspect of vulnerability and adaptation studies.

   - An in-depth assessment of the potential socio-economic and biophysical impacts of climate change on Namibia’s water resources should form the focus of immediate future research. It is recommended that all other research should focus on those impacts that are expected to have specific effects on human livelihoods and well being, and are unlikely to be pursued by the National Programme to Combat Desertification (NAPCOD), the National Biodiversity Task Force or marine resources research that aims to improve understanding of the effects of the natural environment on fish population dynamics. Some suggestions include:-
     - Investigating the direct effects of climate change on food security amongst rural communities. Focus should be on sorghum and millet crop growth, etanga (*Citrullus lanatus*), omakunde (*Vigna unguiculata*), important fruiting and tuberous veldkos species, the potential for increases in crop pests, pathogens and livestock disease, and the adaptation options regarding these impacts.
     - Investigating the effects of climate change and the possible adaptation measures that can be taken on the health of marginalised urban and rural populations in northern Namibia – an area that could become increasingly susceptible to vector borne diseases and other pathogenic invasions from neighbouring states.

2. Adaptation and Disaster Preparedness
More extreme weather events (both droughts and floods) are likely to characterise Namibia’s future climate and it is important to identify cost-effective adaptive management approaches. National preparedness regarding extreme events and the secondary impacts that accompany them (including the threat of bio-invasions, disease epidemics, reduced food security and increased rates of human migration) is required and
national disaster response strategies should become an integral part of Namibia’s sustainable development planning.

Development planning, particularly at the strategic and project levels must take cognisance of the potential impacts of climate change. For example, the allocation of land for specific land-use must consider the potential effects of increasing climatic variability. Similarly, risk assessments within project EA’s must consider the possibility of increased frequency of large flood events.

3. Creating Awareness

In addition to informing policymakers about the possible effects of climate change, decision-makers at all levels including government officials, local and traditional authorities, farmers and the general public should be kept informed about Namibia’s interseasonal and interannual climatic variability. Publications similar to the monthly *WHOT?* Bulletin produced by Namibia’s Meteorological Services are a good example of how relevant climatic information, and the implications thereof, can be provided to all stake-holders.
PART A.

INTRODUCTION
PREAMBLE

Naturally occurring greenhouse gases in the earth’s atmosphere (water vapour, carbon dioxide, methane, ozone and nitrous oxide) have the radiative ability to trap heat and warm up the planet (Figure 1.1). Without this so-called greenhouse effect the average temperature of the Earth’s surface would be -18°C and life as we know it would not exist.

Since the onset of the industrial revolution, human-induced greenhouse gases resulting from the burning of fossil fuels and other activities (Figure 1.2) have increased and accumulated in the atmosphere¹. In addition, deforestation is steadily removing one of the planet’s major natural carbon dioxide sinks. The raised concentration of greenhouse gases is beginning to cause a discernible increase in the Earth’s average surface temperature. This, in turn, has the ability to cause other large scale, long term changes to global climate - generally referred to as the enhanced greenhouse effect, global warming or climate change (Figure 1.2 and Box 2.3).

Developed countries are the main emitters of greenhouse gases. However, the world as a whole will suffer the consequences of climate change and some of the least responsible countries, with the poorest ability to respond, will suffer the greatest impacts. The 13 SADC countries contribute less than 2% of all human-induced global greenhouse gas emissions² but, in the long-term, the region is expected to experience some extremely detrimental effects as result of an altered climate. Namibia, as a developing country located in an arid region where drought and high climatic variability is endemic, and where great demands are placed upon natural resources, is considered to be particularly sensitive to the effects of climate change.

The main objectives of this document are to: -

- Create awareness concerning Namibia’s sensitivity and vulnerability to climate change³; and

- Provide background information in order to lay a foundation for future quantitative vulnerability and adaptation studies.

To meet these objectives this document:-

- Reviews Namibia’s current and possible future climate.
- Provides broad socio-economic scenarios for Namibia and summarises the potential socio-economic impacts of climate change.
- Offers a baseline scenario, incorporating an outline of the growth prospects, current constraints and policies that are expected to influence the future of each vulnerable sector.

¹ Pre-industrial revolution (1850) atmospheric levels of CO₂ are estimated at 280ppm. The 1990 level for modelling purposes is taken at 330 ppm. By 2100 it is estimated that, in the absence of mitigating efforts, this value will reach 555 ppm – a level that is approximately double 1850 levels and is usually referred to as 2X CO₂ (IPCC).
² South Africa is estimated to produce 91% of the total emissions in the SADC region, Zimbabwe 6% and the remaining 11 countries, 3% (African Development Indicators Report, 1997).
³ A country that is sensitive to climate change is not necessarily vulnerable. Vulnerability is determined by the ease with which a country is able to adapt to the changes that occur.
Figure 1.1 Sources and sinks of naturally occurring greenhouse gases and the greenhouse effect

**CO₂ SOURCES**
- Animal and plant respiration.
- Decomposition of organic matter.

**CO₂ SINKS**
Terrestrial, marine and freshwater aquatic plants (photosynthesis).

**METHANE SOURCES**
- Deposits of coal, oil natural gas.
- Guts of ruminating mammals and termites.
- Anaerobic bacteria in soil bogs, marshes (decomposition of organic matter).

**THE GREENHOUSE EFFECT**

Incoming solar radiation

Heat (IR radiation) radiated back from surface

Some IR radiation is absorbed by GHGs and is re-radiated back to Earth. This warms up the atmosphere.

Some IR radiation escapes out to space

EARTH
Continued from page 1.

- Reviews the possible effects of global warming on each vulnerable sector, by superimposing climatic conditions, based on expected climate change scenarios, over each baseline scenario.

Namibia's ability to respond to an altered climatic regime depends on many interlinked factors, including the future population growth rate, economic growth and flexibility, natural resource base status, rates of land conversion/degradation and socio-political stability of the country. Given the inability of experts to accurately predict these circumstances and the timing, magnitude and nature of the expected climatic changes, forecasting Namibia's exact future is not possible. However, by examining some of these issues, this document highlights the importance of considering Namibia's extremely uncertain climatic future as an integral part of all strategic planning.

Figure 1.2. Causes of global climate change and potential effects on Namibia

[Author's compilation]
1.1 Background Information on Namibia

Flanked by the Atlantic Ocean, Namibia lies roughly between 29° and 17° S, on the western side of southern Africa. It covers an area of approximately 823 000 km² and has a coastline of approximately 1600 km. The coastal Namib Desert extends up to 160-km inland and, beyond the Central Plateau, the Kalahari Desert occupies most of the eastern part of the country. Simplified versions of the country’s complex landforms and elevation contours are shown in Figures 1.4 and 1.5. Declared a German colony in 1884, Namibia was conquered by South Africa during World War I. Independence from the South African administration was achieved in 1990. Today, Namibia is divided into 13 regions (Fig. 1.3).

Figure 1.3. Namibia’s Major Towns and Regions

Various Government Gazettes published by the Government of Namibia.

Ministry of Lands, Resettlement and Rehabilitation
Division of Survey and Mapping
1:250000 maps.

* National Remote Sensing Centre 1997
Figure 1.5 Elevation Contours of Namibia (300m intervals)

Contours

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Border

Major Towns

Source:
Ministry of Lands, Resettlement and Rehabilitation
Division of Survey and Mapping

© National Remote Sensing Centre 1997
1.2 Namibia’s Most Vulnerable Sectors

This document considers the possible effects of climate change on Namibia’s seven most vulnerable sectors. Ideally, these sectors should not be studied in isolation, as many interactive links occur between their various climate-driven responses (Table 1.1). Some of these links are broad and clearly apparent – for example, climate induced changes to Namibia’s water resource sector will obviously affect electricity production from hydroschemes, agricultural output from irrigation schemes, the inland fisheries sector and basic human health. Other connections are less discernible. For example, besides exerting a direct effect on Namibia’s marine resources sector, climate driven changes in biodiversity and ecological functioning are likely to affect current rates of land degradation, cause alterations in the distribution and prevalence of pests, weeds and disease vectors and affect riparian vegetation which plays an important role in water purification, flood control and water storage.

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PART B.

CURRENT AND FUTURE CLIMATE
CURRENT CLIMATE

2.1 Precipitation
Similar to coastal desert conditions that prevail in other parts of the world, Namibia’s natural aridity has been maintained and enhanced by the association of a cold, subpolar current with a hot subtropical interior. Although the Benguela current, which sweeps northwards along the coast from the Antarctic, has undoubtedly had a profound influence on the country’s climatic regime for the last 5 – 10 million years, there is evidence that arid and semi-arid conditions have prevailed over much of the country for the last 50 – 80 million years (Ward & Corbett 1995; Seely 1992).

2.1.1 Rainfall
- Most of the country receives summer rain between October and April. Virtually no rain occurs during the rest of the year except in the south-western area (the Sperrgebiet) which experiences rainfall during the winter months (May – August).
- Air masses that bring rain to Namibia originate over the Indian Ocean on the eastern side of the sub-continent. Consequently, most of their moisture is lost by the time they reach Namibia. This has resulted in a naturally arid environment with the following rainfall regime (Figure 2.1):
  - 15% of the country (coastal strip) is a hyper-arid desert receiving on average, < 50mm of rain per annum.
  - 40% of the country is arid savanna receiving on average, between 50 mm and 300mm of rain per annum.
  - 37% of the country receives on average, between 300mm and 500mm of rain per annum and is described as semi-arid.
  - Only 8% of the country (the Caprivi region) receive more than 500mm of rain per annum. (DWA, 1991).
- Rainfall in Namibia is not only sparse but extremely variable (Figure 2.2), a phenomenon that is influenced by a network of global ocean currents, rainfall teleconnections between the Pacific and southern Africa and changes in sea surface temperature (Box 2.1). Throughout most of Namibia, deviation from the mean exceeds 30% and it is common for some seasons to record less than half or more than double the mean precipitation (Figure 2.3). Droughts are common and below average rainfall often occurs for periods longer than 2 years.

Although most of the climatic variability that has characterised southern Africa this century is random, a number of discernible quasi-periodic rainfall oscillations have been reported. Most noticeable of these within the summer rainfall areas is an 18 year oscillation, consisting of approximately 9 year spells that are either predominantly wet or predominantly dry (Tyson, 1986). However, not all areas within the region have been affected equally or at the same time and Tyson (1986) reports that the northwestern parts of the region (including Namibia) have displayed a tendency for a 6-year oscillation. In spite of this, local meteorologist’s state that it is extremely difficult to discern any cyclic or other long-term rainfall patterns for Namibia.
2.1.2 Fog

As a result of the cold Benguela Current, sea surface temperatures close to shore are typically lower than those offshore, where higher evaporation rates prevail. When the relatively warmer moisture laden air over the open ocean flows eastwards and meets the cooler air above the coastline, condensation occurs and advective fog is formed. Precipitation from fog is highest on higher land approximately 20 – 40 km from the coast but can sometimes extend much further inland (Table 2.1). Fog suppresses evapotranspiration and plays a vital role in the ecological functioning of the Namib Desert (Section 8.2.1). Fog days are more frequent during winter.

Table 2.1 Precipitation from fog and rain in the Namib Desert [DRFN unpublished data]

<table>
<thead>
<tr>
<th></th>
<th>COASTAL ZONE</th>
<th>INLAND FOGGY ZONE</th>
<th>MIDDLE ZONE</th>
<th>EASTERN ZONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from coast (km)</td>
<td>0-20</td>
<td>20-60</td>
<td>40-90</td>
<td>70-120</td>
</tr>
<tr>
<td>Rainfall (mm/year)</td>
<td>15.2</td>
<td>18.8</td>
<td>27.2</td>
<td>87</td>
</tr>
<tr>
<td>Fog (mm/year)</td>
<td>34</td>
<td>183.6</td>
<td>30.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Fog days / year</td>
<td>65</td>
<td>87</td>
<td>37</td>
<td>3</td>
</tr>
</tbody>
</table>

Namibia’s Vulnerability to Climate Change 2. CURRENT & FUTURE CLIMATE
Box 2.1 SOME CAUSES OF NAMIBIA'S CLIMATIC VARIABILITY
[Sources: Hutchinson, 1995; Lutjeharms et al 1995; Mason, 1996; Morton, 1998; NMS 1998(b)]

Namibia's natural climatic variability is caused by many interlinked factors including the following:-

**The long distance effect of the North Atlantic**

Deep ocean currents that originate in the north Atlantic drive a global "conveyor belt" of ocean water southwards, around Antarctica and then northwards into the Pacific before returning to the surface. Changes to this circulation pattern are believed to be partially responsible for triggering disruptions in global climate, including the onset of Ice Ages and other, less dramatic, forms of climatic variability in various parts of the world.

**Namibia's Climatic zones.**

Northern Namibia is situated at the interface between the Intertropical Convergence Zone (ITCZ) and the Mid-Latitude High Pressure Zone (MLHPZ). Southern Namibia lies at the interface between the MLHPZ and the Temperate Zone. Both the ITCZ and the Temperate Zone are areas of rainfall while the MLHPZ between them is not. Slight inconsistencies in the extent to which these zones shift in response to the seasonal displacement of the sun are largely responsible for Namibia's rainfall variability.

**El Niño/Southern Oscillation (ENSO)**

These irregular climatic events result from a reversal of the pressure differentials between the east and west Pacific and a breakdown of the prevalent east-west trade winds. In response, a mass of warm water, usually kept in the west, breaks free and moves eastwards towards South America, causing changes in atmospheric pressure and large disruptions to global weather patterns. The combined effect on ocean and atmosphere is termed the ENSO (El Niño/Southern Oscillation) phenomenon. In southern Africa, El Niño events usually herald unwelcome periods of drought, which can last the actual El Niño by up to a year. Anomalies in sea surface temperature (SST), due to El Niños and other factors, are capable of influencing the dynamics of the climatic zones to which Namibia is subjected and are therefore closely associated with the rainfall variability that affects the region. SST impacts on the transfer of heat energy between the sea and the atmosphere and is therefore able to influence wind speed and strength as well as the cloudiness and radiation (energy) balance of the atmosphere.

2.2 Wind

Southerly and southwesterly winds predominate along the Namibian coast (Table 2.2) causing intense upwelling. This wind regime has a profound effect on Namibia's marine ecosystem (Box 6.1) and temperatures along the coast. During autumn and winter hot easterly winds periodically blow from the desert towards the sea, causing above average temperatures at the coast. Winds in the interior display no discernible pattern, but are considerably weaker than those at the coast.

Table 2.2 Namibia's Coastal Wind Regime [van der Merwe 1983]

<table>
<thead>
<tr>
<th>Coastal Settlement</th>
<th>Average Number of calm days per annum</th>
<th>Average number of days with southerly or south westerly winds/year</th>
<th>Average wind speed km/h (southerly and south westerly)</th>
<th>Average number of days with easterly winds/year</th>
<th>Average wind speed km/h (easterly winds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mũwe Bay</td>
<td>38</td>
<td>255</td>
<td>22-32</td>
<td>&lt;20</td>
<td>11-22</td>
</tr>
<tr>
<td>Walvis Bay</td>
<td>84</td>
<td>175</td>
<td>20</td>
<td>&lt;20</td>
<td>11-22</td>
</tr>
<tr>
<td>Lüderitz</td>
<td>39</td>
<td>219</td>
<td>&gt;32</td>
<td>&lt;20</td>
<td>22-32</td>
</tr>
</tbody>
</table>

Namibia's vulnerability to climate change 2. CURRENT & FUTURE CLIMATE
Figure 2.2 Average annual rainfall in Namibia (volumetric) 1915-1997.
[ P. Hutchinson unpublished report, 1998]
Figure 2.3 Coefficient of Variation (%) of Annual Rainfall

[Source: Botha 1997]

Coefficient of Variation = Standard Deviation/Mean \times 100
Figure 2.4 Maximum and Minimum Temperatures for Namibia

[van der Merwe 1983]
Figure 2.5. The Water Deficit For Namibia (mean annual Rainfall - mean annual evaporation in mm)

Water Deficit

(Mean Annual Rainfall - Mean Annual Evaporation in mm)

Source:
Ministry of Agriculture,
Water and Rural Development
Department of Water Affairs

© National Remote Sensing Centre 1997
2.3 Temperature
- The highest temperatures are recorded in Caprivi and the Orange River basin. On average, during the hottest months, maximum temperatures across the country vary from 31°C to 40°C (Figure 2.4) but have been known to reach as high as 48 °C at some localities. On average, during the coldest months, minimum temperatures across the country vary from 2 °C to 10 °C but may reach as low as -10 °C at some localities (van der Merwe 1983).
- The cold Benguela current affects temperatures along Namibia’s coast which average between 15 °C – 20 °C. However, the periodic occurrence of east winds during autumn and winter can cause these temperatures to rise dramatically above this average.\(^2\) Sea temperatures closer to shore are cooler than those out to sea as the prevailing southerly and south westerly winds usually result in a north westerly flow of warmer surface water, resulting in the upwelling that drives the Benguela ecosystem (Chapter 5).
- Fog affects the duration of sunshine along the coast but the central and southern interior experience an average of 10 hours of sunshine per day (DWA 1995).

2.4 Evaporation
Namibia’s interior plateau is characterised by an extremely high evaporation rate which exceeds average rainfall (van der Merwe 1983). Potential Evapotranspiration (PET) is the evaporative demand of the atmosphere on plants and depends on air temperature, humidity, wind speed and solar radiation or daylight hours (Hutchinson, 1995). PET affects the soil water balance and thus, the growth potential of vegetation. Every 1 °C rise in temperature corresponds to an annual PET rise of approximately 5.25% ± 1.55 (Le Houérou, 1996). The water deficit for Namibia (mean annual rainfall – mean annual evaporation in mm) is depicted in Figure 2.5.

FUTURE CLIMATE

2.5.1 Introduction
Climate, both local and global, is the result of complex processes that occur in response to solar energy. The interacting components that drive climatic systems include the atmosphere, oceans, land surface, the cryosphere and biosphere. Climate change science is complicated by the fact that many of the feedback mechanisms that occur between these various components are not yet fully understood.

Many seemingly unrelated factors play a role in determining global climate and are likely to be affected by human induced environmental change. For example, recent research indicates that changing sea levels are capable of triggering an increase in volcanic eruptions, an important natural cause of climatic variability (Box 2.2).

Global climate is in a constant state of flux and, over the past 500 000 years, the regional climate has oscillated between cold and warm periods, broadly in keeping with global

---
\(^2\) Temperatures as high as 40.1 °C have been recorded in the coastal town of Lüderitz during autumn and early winter (van der Merwe 1983). Walvis Bay recorded a maximum temperature of 38.4 °C in mid-May 1998 (NMS 1998)
glacial and interglacial phases (Hulme et al 1996). Thus, our estimation of climate change resulting from the enhanced greenhouse effect must take into account the fact that large scale, naturally induced climate changes have occurred in the past, and that they will occur again in the future (Pirie 1995).

Box 2.2 VOLCANIC ACTIVITY AND CHANGING CLIMATE
[Sources: McGuire, 1997; Morton, 1998]

Recent research indicates that changing sea levels are capable of causing an increase in volcanic eruptions. Volcanic activity cools down the Earth by injecting vast quantities of sulphur aerosol particles into the atmosphere. These particles counteract the effect of greenhouse gases by reflecting solar radiation back into space.

Although volcanic eruptions cool down the Earth’s surface, they are capable of heating up the stratosphere and causing changes in stratospheric wind activity. This in turn is capable of affecting the troposphere below and, consequently, changing the way in which the North Atlantic Oscillations (NAO) and other key determinants of global climate respond (Box 2.1).

2.5.2 Climate Change Scenarios
Box 2.3 provides a summary of the IPCC’s IS92a Greenhouse Gas Emissions Scenario (See also Appendix 1) together with some future predictions regarding the effects of global warming.

Box 2.3 A SUMMARY OF THE IS92a GREENHOUSE GAS EMISSIONS SCENARIO AND FUTURE PREDICTIONS FOR THE ENHANCED GREENHOUSE EFFECT [ WMO & UNEP 1995; UNEP 1996; IPCC, 1997]

The IS92 Greenhouse Gas Emissions Scenario offers a mid-range estimate of future emissions and assumes only a modest degree of policy intervention to limit emissions. It is based on the following assumptions:

- World population will reach approximately 10 billion by 2050, after which growth rates slow down resulting in a global total of 11.5 billion in 2100.
- Economic growth rates will decline after 2025. The amount of energy consumed per unit of output declines in OECD countries and China but remains about the same in developing countries through 2025.
- Reliance on natural gas and petroleum is assumed to increase steadily to 2025 and then decline until consumption falls below 1990 levels by 2100. Consumption of coal increases until consumption is seven times current levels by the year 2100.
- The price of solar power will drop and the price of nuclear power will increase until they are about the same level.
- Net CO₂ emissions from deforestation remain at roughly 1 Gt/year, declining after 2025 as land clearing diminishes. CH₄ emissions from livestock are projected to double by the year 2025.

Thus, by 2100 anthropogenically induced:-
- CO₂ emissions are expected to triple;
FUTURE BROAD EXPECTATIONS RESULTING FROM GLOBAL WARMING

Based on the range of sensitivities of climate to changes in the atmospheric concentrations of greenhouse gases and aerosols, climate models estimate that:

- The mean annual global surface temperature is likely to increase by 1.5 – 4.5°C by 2100 (compared with 1990). This average rate of warming over the next 100 years will be greater than any that has occurred in the past 10 000 years and the period over which civilisation developed.
- The global mean sea level is likely to increase by 23 – 96 cm by the year 2100 above mid-1990’s levels.
- Changes in the spatial and temporal patterns of precipitation will occur.

2.5.2.1 Limitations of GCMs
The most viable tool for developing regional climate change scenarios involves the use of General Circulation Models (GCMs) which are mathematical representations of the processes that determine global and regional climate. Unfortunately, GCMs are constrained to a grid resolution of between 3° and 5° of latitude and longitude and are thus unable to resolve local scale parameters (Hewitson 1995). Furthermore, most current GCMs make limited or no allowance for:

- Future variations in solar activity or large volcanic eruptions;
- The effects on climate of atmospheric aerosols resulting from industrial emissions, biomass burning or dryland aeolian processes;
- Future changes in land use (deforestation); and
- Interactions between stratospheric ozone depletion and surface climate.

Given these limitations, it is not advisable to focus on any one single scenario for changes in climate nor to rely on these scenarios as predictions or forecasts. Rather, scenarios should be used to create awareness concerning the potential changes that may result from an enhanced greenhouse effect (Glantz 1992, Hulme et al. 1996). Researchers are constantly improving old, and developing new, GCM’s. As a result, their ability to broadly represent the way in which climate will change over future decades is steadily improving.

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3 Downscaling, which relies on empirical relationships between synoptic and local scales, offers a potential solution to overcome the limitations of GCM’s (Hewitson1995).
2.5.2.2 Changes in Global Temperature

- Increased temperatures are expected to be greatest at the poles and will be accompanied by increases in evaporation and potential evapotranspiration (Schulze 1993).
- The Northern Hemisphere is expected to warm more than the Southern Hemisphere because it has a higher proportion of land to ocean (Schulze 1990).
- Diurnal minimum temperatures are hypothesised to increase more than maximum temperatures and seasonally, winter warming is likely to be greater than summer warming (IPCC 1992).

Almost all GCM's agree on the average global temperature increases that might accompany a doubling of atmospheric CO₂ (Box 2.3). However they are in serious disagreement about the regional impacts of global warming on climatic variability, precipitation and soil moisture.

2.5.2.3 Climate Change Scenarios for the Terrestrial Region of SADC

In their 1996 study "Climate Change and Southern Africa: an exploration of some potential impacts and implications in the SADC region", Hulme (et al) link results from a GCM and a simple climate model to define a 'core' scenario for climate change for the SADC region for the 2050s decade (Figure 2.6). Implications for Namibia based on this scenario are summarised in Table 2.3.

In addition, Hulme et al (1996) describe two alternative scenarios for the region – a 'wet' and a 'dry'. Most of the region dries under the latter by displaying a 2.5-10% reduction in precipitation while the former implies increases in precipitation of up to 20% for some parts of the region. Sea level rise scenarios are discussed in detail in Chapter 9.

Meteorologists from the NMS have begun to test Transient Models and several GCM's from the US Country Studies Programme with the aim to create plausible future climate scenarios for Namibia (Appendix 1). These investigations are still at the experimental stage and have not been used during this phase of Namibia's country study.

Table 2.3 The UKTR 'Core' scenario for the SADC Region. Predictions for Namibia by the 2050's decade[ adapted from Hulme et al 1996]

<table>
<thead>
<tr>
<th>CORE SCENARIO</th>
<th>IS92a4</th>
<th>Estimated increase in PET.</th>
<th>Central and eastern Namibia</th>
<th>4-8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Climatology</td>
<td>1961-1990</td>
<td>Estimated change in rainfall</td>
<td>North Central Namibia</td>
<td>8-12%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Caprivi</td>
<td>12-16%</td>
</tr>
<tr>
<td>Estimated increase in average annual temperature</td>
<td>Average warming of 1.7 °C. Greatest warming (−2°C) occurs over the interior upland plateaux of the SADC region including eastern Namibia.</td>
<td>Estimated change in rainfall variability4</td>
<td>Increased variability of between 5 and 15%.</td>
<td></td>
</tr>
</tbody>
</table>

4 The IPCC's reference (IS92a) greenhouse gas emissions scenario is discussed in more detail in Appendix 1.

5 Reliability of these figures is low as climate change experiments using GCMs do not generally capture all the factors that determine rainfall variability (Hulme et al 1996).
Figure 2.6 The UKTR ‘Core’ Climate Change Scenario for the SADC region [After Hulme et al 1996].

**Average Annual Potential Evapotranspiration for 1961-1990 and potential changes by 2050 under the ‘core’ scenario.**

**1961–90 Annual Penman PE**

**Annual PE Change – Core Scenario (UKTR)**

**Average Annual rainfall for 1961-1990 and percent changes by 2050 under the ‘core’ scenario.**

**1961–90 Annual Rainfall**

**Annual Rainfall Change – Core Scenario (UKTR)**

**Interannual rainfall variability (Coefficient of variation) for 1961-1990 and potential changes by 2050 under the ‘core’ scenario.**

**1961–90 Interannual Rainfall Variability**

**Annual Variability Change – Core Scenario (UKTR)**
In spite of the fact that many future scenarios for climate change are possible, it is generally accepted that overall conditions in the sub-tropical and winter rainfall areas of southern Africa are likely to become hotter and drier by the year 2050. Summer rainfall over the tropical areas of the region may increase. Increased variability is also likely for the first half of the new century (Tyson 1991; Zhakata, 1996). If this general prediction is accurate, then the trend towards more frequent and severe droughts can be expected to continue for most of Namibia.

2.5.2.4 Climate Change Scenarios for the Marine Environment
The Hadley Centre’s coupled Atmosphere-Ocean GCM has currently been identified as the most appropriate model to use for investigation the effects of climate change on southern Africa’s marine system (Lombard 1998). For the purposes of future studies, projections from this model could be referred to. Although many interactive effects and atmospheric/oceanic feedback responses are anticipated as a result of global warming, the rise in sea-level and enhanced sea surface temperatures (SST) will be the most discernible impacts affecting the ocean and coastal systems as a result of climate change.

For middle latitudes, average air temperatures are expected to rise by 1.2 °C in the 2020’s, 2.1 °C by the 2050’s and 3.2 °C in the 2080’s. According to the Hadley Centre model, sea surface temperatures are expected to lag slightly behind these figures (Lombard 1998). Sea-level rise scenarios are discussed in detail in Chapter 9.

2.6 Recent Trends – Climate Change or Natural Climatic Variability?

During the last 2 decades extreme record-setting weather events have occurred around the globe. For each month this year (1998) average global temperatures have been the highest on record (Glantz 1998).

Some environmentalists contend that southern Africa is already experiencing the consequences of an enhanced greenhouse effect – temperatures in the region have risen by 0.5 °C during the past century and the 1980-1995 decade has been the warmest and driest since 1900 (Hulme et al, 1996). Local hydrologists report that flow regimes of rivers in the region have displayed a noticeable decline since the early 1980’s, a situation that has not altered, even in years of good rain (Van Langenhove et al, 1998). Furthermore, meteorologists agree that El Niño events are becoming more frequent and intense.

Thus, although it is accepted that human induced greenhouse gas emissions will affect global climate (Box 2.3), it is difficult to ascertain whether the higher temperatures and more prevalent droughts experienced in recent decades are actually a manifestation of global warming or simply the result of natural climatic variability.

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6 Strong, regular El Niño events were recorded from the 1870’s until the early 20th century. They died down (except for one major event in 1939-42) until the 1950’s when a more robust pattern emerged (on average occurring every 4 years and lasting for an average of 18 months) (Charlesworth 1997). Their frequency and unpredictability has increased dramatically during the past 2 decades (Glantz, 1999a). A direct link between the more prevalent El Niño events and anthropogenically induced global warming has not yet been established.
2.6.1 Is Namibia Becoming Hotter?
Mean temperatures for Windhoek between 1950 and 1997 have displayed an average increase of 0.023 °C/annum (Figure 2.7). The 1980's and 1990's have been the hottest decades this century. In accordance with global trends, several records were broken for maximum temperatures during the summer of 1997/98. February 1998 was particularly hot, and differences from normal mean daily maximum temperatures for this month exceeded 4°C for most of the country and reached over 6°C at Sitrusdal (Outjo). During this month three stations viz. Hardap, Sitrusdal, Okaukuejo (Etosha National Park) achieved the highest temperatures of their entire record (NMS, 1998). Four other stations achieved new records for the highest temperatures in any February (Table 2.3). Prevailing El Niño conditions were blamed for these unusually high temperatures (ibid).

Table 2.3. Highest Temperatures in February (Source: NMS, 1998)

<table>
<thead>
<tr>
<th>STATION</th>
<th>Highest temperature in February °C</th>
<th>Previous</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windhoek (MET office)</td>
<td>36.9</td>
<td>35.8</td>
<td>1983</td>
</tr>
<tr>
<td>Koeckmanskloof</td>
<td>42.0</td>
<td>41.3</td>
<td>1969</td>
</tr>
<tr>
<td>Okaukuejo (Etosha)</td>
<td>42.2</td>
<td>39.6</td>
<td>1983</td>
</tr>
<tr>
<td>Mowe Bay</td>
<td>30.8</td>
<td>29.0</td>
<td>1974</td>
</tr>
<tr>
<td>Sitrusdal (Outjo)</td>
<td>40.5</td>
<td>38.4</td>
<td>1983</td>
</tr>
<tr>
<td>Pelican Point</td>
<td>27.6</td>
<td>26.4</td>
<td>1978</td>
</tr>
<tr>
<td>Hardap Dam</td>
<td>41.9</td>
<td>38.9</td>
<td>1980</td>
</tr>
</tbody>
</table>

Figure 2.7. Windhoek Mean Temperatures (°C) (1950-1997) [NMS, unpublished data]

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7 Windhoek is the only locality that has sufficient data to be able to observe these changes.
2.6.2 Is Namibia Becoming Drier?

The long-term (1915-1997) mean (volumetric) rainfall for Namibia is 272 mm (Hutchinson 1998). Based on this figure a slightly below average rainfall spell occurred during the 1920 –1950 period. This was followed by a slightly above average spell until 1970. Since then, volumetric rainfall has declined steadily and the last two decades have been the driest this century (Figure 2.2). 1994 was the second driest year on record (after 1932) and 1988 and 1997 were the only years during the 16 year period between 1981 and 1996 that produced above average rainfall (Figure 2.8).

Figure 2.8 Deviation from average rainfall in millimetres (1981-1997) [Hutchinson, unpublished data]

2.7 Preparing for the Future

- El Niño-related departures from average climatic conditions are an integral part of the global climate system and, although they often herald unwelcome periods of drought, should not be viewed as unexpected. Policy makers, governments and scientists in southern Africa are increasingly focusing on El Niño events as a tool for forecasting the possibility of droughts and floods months in advance. Namibia’s Meteorological Services receive El Niño forecasts from the European Centre for Middle Range Forecasting (ECMWF), the United Kingdom Meteorological Office (UKMO) and several institutions in the USA, and make this information available through the Windhoek Weather Bureau.

- The Windhoek Weather Bureau has recently begun to produce two bulletins for distribution to Government Ministries, farmers and other interested parties. The Ten-day Rainfall Bulletin is distributed during the rainy season and the WHAT’? Bulletin is produced monthly during the rest of the year. These provide valuable information on current weather, longer range forecasting (e.g. the status of El Niños), incidence of flooding and bush fires.

- The establishment of Normalised Difference Vegetation Images (NDVI) from NOAA satellites and the use of meteostat based crop yield estimate models are being investigated by the NMS in order to help monitor forage conditions over Namibia and
provide simple, rapid information for crop planting. These systems will prove invaluable to the agricultural sector of the country (Section 7.2.6).

- Efforts to test various GCMs have begun (Appendix 1). The recently acquired scenario generator, MAGICC/SCENGEN, will provide a useful tool for helping to create climate change scenarios for Namibia’s future specialised studies on vulnerability to global warming.

2.8 Conclusions
Due to the different greenhouse gas emissions scenarios the world may follow, the various assumptions that can be made concerning the sensitivity of climate to altered atmospheric composition and the different climate models that can be used to simulate future climate, several future climate scenarios are possible for Namibia. Nevertheless, temperature trends this century and rainfall patterns since the early 1980’s, do reflect the outcome of many scenarios which imply a hotter, drier future for most of the SADC region. Furthermore, accelerating cycles of shock events (droughts, floods, hurricanes and typhoons) appear to be increasing globally and it is quite clear that decision-makers must begin to plan in the face of considerable climatic uncertainty. Thus, a more integrated approach to management has become a critical priority. In order to support this approach, Namibia’s meteorological services will need to improve existing databases (particularly the reconstruction of long series of temperature and rainfall data) and continue to become increasingly proactive regarding the distribution of relevant climatic information.

The generation of plausible future climate scenarios that are specific to Namibia will provide essential material upon which to build all future in-depth, national climate change impact studies and it is important that current work in this field is continued.
3.1 Current Population
In 1995 Namibia’s population was estimated to be 1.61 million and growing at a rate of approximately 3.2% (UNDP 1996).

- Population density, estimated to be on average 1.7 people per km², varies enormously across the country:
  - The Cuvelai drainage area in the north (approximately 10 000 km², or 1% of the country) is the home of 28% of Namibia’s population. Population densities here can reach as high as 100 people per km²;
  - Only 7% of the population live in the southern areas where population densities are as low as 0.5 people per km² (NPC 1997(a)).

- An estimated 68% of the total population live in rural areas and 32% in urban areas. However, rapid urbanisation has occurred in recent years, with some urban centers growing at a rate well above the average 5% per annum.

- In 1991 children aged between 0 – 14 years constituted 42% of the population while persons of 65 years or older represented less than 5% of the total population (UNDP, 1996).

- The current fertility rate in Namibia is estimated at 6.1 children per woman. Women living in Namibia’s urban areas with a secondary or higher education have one-third fewer children than those without an education living in rural areas (Table 3.1). This supports the fact that one of the most effective ways to reduce population growth is to ensure that girls are well educated.

<table>
<thead>
<tr>
<th>Table 3.1 Human Fertility in Namibia</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Source: in Barnard,1998]</td>
</tr>
<tr>
<td>Mean total fertility (children/women)</td>
</tr>
<tr>
<td>Rural women</td>
</tr>
<tr>
<td>Urban women</td>
</tr>
<tr>
<td>All women</td>
</tr>
<tr>
<td>No education</td>
</tr>
<tr>
<td>Completed Grade 7</td>
</tr>
<tr>
<td>Completed Grade 10</td>
</tr>
<tr>
<td>Completed Grade 12</td>
</tr>
</tbody>
</table>

3.2 Current Economic Trends
Namibia’s national economy relies heavily on services and natural resources (Figure 3.1). Although the overall contribution by agriculture to the GDP is modest, it remains the
main source of employment and livelihood for the majority of the population (approximately 70%).

Scarcity of water and episodic drought limit national economic development and the economy is not sufficiently diverse to cushion it against the fluctuating international and environmental conditions that affect the mining, fishery and agricultural sectors. Furthermore, the country’s remoteness has restricted trading opportunities and has resulted in a comparatively high cost of living.

![Figure 3.1. Average broad sector contribution to GDP (1990-1997)]

[CSO National Accounts 1998; DEA estimate for tourism]

![Pie chart showing the contribution of different sectors to GDP]

- mining 21%
- other manufacturing 9%
- tourism 3%
- agriculture (mainly livestock) & meat processing 9%
- marine fishing and fish processing 7%
- other services 51%

Table 3.2 GDP Growth Rates Since 1990
[Source: NPC 1998]

<table>
<thead>
<tr>
<th>Period</th>
<th>GDP (N$ million)</th>
<th>Real change in GDP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>6323</td>
<td>-1.2</td>
</tr>
<tr>
<td>1991</td>
<td>6980</td>
<td>10.4</td>
</tr>
<tr>
<td>1992</td>
<td>7418</td>
<td>6.3</td>
</tr>
<tr>
<td>1993</td>
<td>7271</td>
<td>-2.0</td>
</tr>
<tr>
<td>1994</td>
<td>7758</td>
<td>6.7</td>
</tr>
<tr>
<td>1995</td>
<td>8021</td>
<td>3.4</td>
</tr>
<tr>
<td>1996</td>
<td>8256</td>
<td>2.9</td>
</tr>
<tr>
<td>1997</td>
<td>8401</td>
<td>1.8</td>
</tr>
</tbody>
</table>

- Between 1990 and 1996 Namibia’s economy is estimated to have grown at an average annual rate (compounded) of 4.3 % (Table 3.2).
- Exports (mainly ores, minerals, fish products, live animals, animal products and meat products) are valued at more than 50% of GDP. The large volume of imports generates about 30% of government revenue through import taxes (Blackie 1998).
PART C
SOCIO-ECONOMIC SCENARIOS AND IMPLICATIONS OF CLIMATE CHANGE

CURRENT AND FUTURE POPULATION AND ECONOMY

SOCIO-ECONOMIC IMPLICATIONS OF CLIMATE CHANGE
• The relatively high average per capita income of N$ 6 998.00 (US$ 1 666.00) per annum disguises the fact that the top 1% earners in Namibia have a total annual income that exceeds the total income of the bottom 50%. In 1994, approximately 47% of the population were classified as poor\(^1\), of which approximately 13% were classified as severely poor\(^2\) (NPC, 1997).

• Commercial resources (petroleum products, electricity and coal) account for 78% of energy consumption. However, traditional fuels (wood, charcoal, and livestock waste) are the primary energy source for approximately 60% of Namibian households (Byers 1997).

• Only a third of the economically-active population is employed in the formal sector and the average economic growth rate per annum is too low to generate adequate jobs for the approximately 20 000 new entrants into the labour market each year (NPC, 1997). In 1996 combined adult unemployment and underemployment had reached 60% of the potential labour force (in Schutz, 1998). Few formal sector jobs are found in the heavily populated north and there is an urgent need for more labour-intensive and geographically-dispersed growth (Ashley & Barnes, 1996).

3.3 Future Scenarios
Climate change impact studies require an assessment of the potential effects of global warming on the country’s future society and economy. For this purpose it is important to create scenarios that reflect the expected changes in the country’s demographic profile and economic output.

3.3.1 Population Growth and Implications
• At current growth rates, Namibia’s population will increase to approximately 1.9 million by 2000, and 3.5 million by 2021 (NPC, 1997). Growth rates are expected to remain positive for several decades. This implies a high dependency rate which will place a tremendous burden on the future economy.

• The exact effect of the HIV/AIDS epidemic on these projections is uncertain. Namibia is one of the countries where the disease is reported to be growing fastest (Westley & Check 1998). Recent models suggest that by 2016 the national population growth rate could drop to as low as 0.1% per annum as a result of the disease (O Jakobsen, pers. comm. 1998). Whatever the scenario, it is accepted that over the next 10 – 15 years, the HIV/AIDS epidemic will cause an increase in mortality rates, reduce fertility, lower population growth rates and place tremendous strain on Namibia’s future economy (Box 3.1).

• Rapid urbanisation is unlikely to abate and by 2006, 43% of the projected population of the country can be expected to be residing in urban areas (NPC, 1997). In Namibia, migration into the towns has resulted in the development of sprawling informal settlements on the outskirts of formal urban areas. Urbanisation and industrialisation are likely to be accompanied by changes in lifestyle that result in increased demands for both water and energy (WRI 1998). Nevertheless, some benefits may be gained from migration into urban areas - direct pressure on the agricultural land can be relieved, services can be more easily and cheaply provided

---

\(^1\) Households where more than 60% of the value of consumption is spent on food.

\(^2\) Households where more than 80% of the value of consumption is spent on food.

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Namibia’s Vulnerability to Climate Change: Socio-Economic Overview
and wages earned in urban centres can help to supplement the poorest of rural families (Dalal-Clayton 1997). However, urban migrants are finding it increasingly difficult to find employment and Namibia’s towns and cities are experiencing a noticeable rise in crime.

- It is unlikely that the government will be able to increase its current high budgetary allocation (28%) for education. If population growth rates remain uncurtailed it will become increasingly difficult to combat illiteracy and uplift the skills of most Namibians (NPC, 1997). Furthermore, unless there are significant improvements in the management and productivity of natural resources, it seems certain that the Namibian economy will be unable to support the future population implied by existing growth rates and current standards of living (Dewdney, 1996).

Box 3.1 THE FUTURE IMPACT OF HIV/AIDS
[Sources: Whiteside, 1994; NPC, 1997; Westley & Check 1998]

Between 1986 and 1997 40 000 HIV related infections were reported in Namibia - 10 000 of which were recorded in 1997 alone. In 1996 AIDS was the major cause of death in the country (12.4% of all reported deaths) even though it is generally under-reported and often not noted on death certificates. Namibia is one of the countries in the world where the disease is believed to be growing fastest, with the increase in reported HIV incidence between 1994-1997 being over 100%.

Most epidemiologists predict that the numbers of HIV-positives in the sexually active population are unlikely to exceed 20-40% at the peak of the epidemic and, in the light of the rapid population growth rates in the region, will not cause population numbers to decline. Nevertheless, annual population growth rates are likely to drop over the next few decades as a result of the disease and the epidemic will have a significant impact on economic growth throughout the region. The economically-active section of society will be hit hardest by the disease and manpower will be reduced. Health care services will require considerable support and the increase in the number of orphans will demand intensified efforts from social service agencies.

The epidemic, still believed to be in its early stages in Namibia, is expected to spread rapidly due to the increase in internal and cross-border migration that will accompany the completion of the Trans-Caprivi and Trans-Kalahari highways.

Regional co-operation is required to help combat the spread of AIDS and research is urgently needed on the sectoral and macro-economic effects of the disease, in order to plan for its projected impacts.

3.3.2 Economic Growth Expectations
Namibia’s economic growth prospects, as depicted in NDP 1, are summarised in Box 3.2. The most prominent expectations are mentioned below.

- Fishing, fish processing and tourism are the sectors expected to display strongest growth in the immediate future (until approximately 2010). Manufacturing, although not likely to show any dramatic growth by 2000, is expected to flourish in decades to come.
- Increased energy output will accompany the development of the Kudu Gas Field and the establishment of a large hydroelectric power plant on the Kunene River.
- The development of Economic Processing Zones centred in Oshikongo and Walvis Bay is expected to promote economic diversification, generate employment
opportunities, lead to an improvement in physical services and encourage foreign investment in the country.

- The Trans-Kalahari highway (completed in 1998), which shortens the road distance between Walvis Bay and Johannesburg in South Africa, and the Trans-Caprivi highway, which provides a continuous tarred road to the north eastern border with Botswana, Zimbabwe and Zambia, are likely to enhance trade between Namibia and other SADC countries.

Due to considerable uncertainty regarding the growth of the manufacturing industry, the recovery of marine fish stocks, the interannual productivity of the Benguela ecosystem (Box 6.1), and the impact of the HIV/AIDS epidemic (Box 3.2), it is extremely difficult to determine with any degree of accuracy, a medium to long term future economic scenario for Namibia. However, in order to give some indication regarding expected future economic growth, two scenarios (one pessimistic and one optimistic) to the year 2017 have been created (Table 3.2). The pessimistic scenario assumes lower growth for most sectors and incorporates indirect impacts on the economy (e.g. increased demands on health and social services) and greatly reduced population growth rates as a result of the HIV/AIDS epidemic (Section 3.4). The optimistic scenario is based on a good recovery of fish stocks to maximum sustainable yields by 2016. It includes a corresponding growth in fish processing and continued growth of tourism at 10% per annum. It assumes current population growth rates that do not take HIV/AIDS into account.

**Box 3.2 SOME SECTORAL GROWTH PROSPECTS** [Adapted from Dewdney 1996]

**Commercial Agriculture** is expected to experience very little growth in response to unfavourable climatic conditions and declining meat and livestock prices in South Africa and the EU.

**Subsistence Agriculture** output expected to grow as a consequence of effective implementation of the new agricultural policy involving improved extension services, technology and access to credit.

**Marine Fishing** is expected to grow with increases in TAC’s but tapers off as the maximum sustainable yields are reached between 2010 and 2016.

**Fish Processing** grows in response to increased catches, better access to markets (particularly within SADC) and long-term fishing rights encourage greater onshore processing.

**Meat Processing** grows as a result of better access to markets and utilisation of diversified products such as game meat.

**Hotels and Restaurants** increase as a result of a rapidly expanding tourism industry.

**Water** remains limited by increasing costs to establish new water supply infrastructure.

**Electricity** output is likely to improve as a result of the Kudu Gas Project and probable development of a large hydroelectric dam on the Kunene River.

**Transport And Communication** grows as a consequence of the upgrading of the Walvis Bay Harbour, the opening up of the Trans-Kalahari and Trans-Caprivi highways, greater regional economic integration and increased tourism.

**Trade** grows in response to increased foreign tourism and improved transport and communication.

**Manufacturing** is expected to grow in response to new policies, a more liberalised trading environment, tax incentives, improved investment promotion, and the establishment of Export Processing Zones.

**Mining.** Diamond mining initially experiences modest growth as offshore operations increase in response to the closing down of onshore mines. The only source of growth during the forthcoming years is from the Skorpion Zinc Mine near Rosh Pinah. Overall, in total, this sector will experience no growth and will eventually decline as resources are depleted during the latter half of the next century.
Table 3.2 Predicted economic growth rates (% per annum) 1998 – 2017. [Blackie, 1998]

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>PESSIMISTIC SCENARIO</th>
<th>OPTIMISTIC SCENARIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Fisheries</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Mining</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Electricity and water</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Fish processing</td>
<td>8-9</td>
<td>8-9</td>
</tr>
<tr>
<td>Meat processing</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>5-7</td>
<td>5-6</td>
</tr>
<tr>
<td>Hotels and restaurants</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Community and social services</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Whole economy</td>
<td>2-3</td>
<td>3-4</td>
</tr>
</tbody>
</table>
**SOCIO-ECONOMIC IMPLICATIONS OF CLIMATE CHANGE**

### 4.1 Namibia’s sensitivity and vulnerability to Climate Change

Namibia’s current high population growth rate, resource based economy and extreme climatic conditions have a profound effect on the nature and rate of land conversion, land degradation and urbanisation. Figure 4.1 summarises some of these interlinked environmental, climatic and social pressures and highlights Namibia’s *sensitivity* to a future climatic regime that is likely to become hotter, drier and more variable (Section 2.5.2). Based on the possible future socio-economic scenarios discussed in Section 3.3.2 some potential constraints for each sector (independent of climate change) are briefly summarised in Table 4.1. Included in this table is an overview of the additional socio-economic consequences that could result from global warming.

**Table 4.1 Summary of Namibia’s future socio-economic challenges and the potential implications of climate change.**

<table>
<thead>
<tr>
<th>Climate sensitive sector</th>
<th>Expected future socio-economic challenges independent of climate change</th>
<th>Possible additional socio-economic challenges due to climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Increased demand for food. Increased food imports</td>
<td>Reduced contribution to GDP. Reduced meat exports. Increased food imports. Reduced household food security.</td>
</tr>
<tr>
<td>Water</td>
<td>Increasing water demand. Increasing costs of supply.</td>
<td>Reduced water availability and quality. Increased cost of water supply.</td>
</tr>
<tr>
<td>Fisheries</td>
<td>Increasing demand on available stocks.</td>
<td>Reduced contribution to GDP. Reduced exports. Reduced employment opportunities. Development of new fishing fleets capable of travelling greater distances to new fishing grounds.</td>
</tr>
<tr>
<td>Coastal Zones and systems</td>
<td>Increasing urbanisation. Increasing threats to coastal habitats.</td>
<td>Increased annual capital costs for protection of urban centres (sea-level rise). Reduction in tourism potential.</td>
</tr>
<tr>
<td>Ecosystems and protected areas</td>
<td>Increased human demands and disturbance. Increased poverty (reduced rural household food security).</td>
<td>Increased loss of species and natural ecosystems. Increased poverty (reduced rural household food security). Loss of tourism potential.</td>
</tr>
<tr>
<td>Health</td>
<td>Continued improvement of primary health care but increased mortalities and health care and social service costs as a result of HIV/AIDS.</td>
<td>Increased mortalities (heat related deaths, vector and water borne diseases). Increased health care costs.</td>
</tr>
<tr>
<td>Energy</td>
<td>Increasing demand. Increased output (Kudu gas and Kunene hydropower project).</td>
<td>Reduced hydroelectric power output. Increased electricity demand (mainly air conditioning and other coolants).</td>
</tr>
<tr>
<td>Urban settlements</td>
<td>Increased costs of supplying and maintaining essential services to rapidly growing informal settlements.</td>
<td>Increased migration into towns. Increased costs of supplying and maintaining essential services.</td>
</tr>
<tr>
<td>Rural settlements</td>
<td>Continued improvements regarding provision of clean water supplies and other services but increased rural to urban migration.</td>
<td>Increased poverty with loss in agricultural productivity. Increased rural to urban migration. Increased health problems.</td>
</tr>
</tbody>
</table>

*See Section 11.5.2*
Figure 4.1 Some interlinked climatic, environmental and social stresses that currently affect Namibia

- **Pressure on Resources**: Water, land, wildlife.
- **Expanding Population**
- **Poverty**: Limits opportunities for sustainable development
- **Rapid Urbanisation**: Threats to human health, unemployment and crime
- **Environmental Degradation**: Habitat conversion; biodiversity loss; soil erosion
- **Pollution**
- **Current Climate**: High temperatures, low rainfall, episodic drought

*Namibia’s Vulnerability to Climate Change 3&4 Socio-Economic Overview*
From this Table it appears that climate change may not create new problems for Namibia's society and economy as much as it is likely to perturb existing ones. Succeeding chapters in this document bring attention to the potential effects of climate change on Namibia's water, fisheries, agriculture, wildlife, health and energy sectors. Although the cost estimates of these impacts will be difficult to ascertain, future in-depth climate change studies must attempt to assess their value in order to help guide macroeconomic policy and planning. Currently, a broad best-guess estimate for developing countries assumes the costs for a doubling of atmospheric CO\textsubscript{2} to be 2 – 9% of GDP (WMO & UNEP 1996). Namibia's high sensitivity to the potential effects of climate change implies that it will incur high damage costs and adaptation measures are likely to require considerable capital, time and skills.

As a country with low economic growth and flexibility, Namibia currently has limited capacity to adapt and therefore is considered to be highly vulnerable to the effects of climate change. However the country’s future economy and social limitations will ultimately determine its vulnerability to global warming. It is clear that a reduction in poverty and the achievement of reasonable and sustainable economic growth will be essential to help reduce the effects and costs of climate change.

4.2 Current Policy and Action

This section offers a brief overview of some current national policies directly relating to poverty abatement, sustainable development and population reduction, thus offering some insight into Namibia's socio-economic future and how well the country will be able to adapt to climate change conditions.

Poverty

One of the biggest challenges facing the Namibian government has been to address the unequal distribution of income and assets that prevailed during the colonial era. Poverty increases susceptibility to drought, limits opportunities for sustainable resource management and reduces a country's ability to adapt to projected climate changes (IPCC, 1997). In the past a number of short-term measures were implemented to reduce poverty, such as food aid and subsidies for livestock, crops, housing and water (Dewdney, 1996). Ironically, many of these measures, particularly those that form part of drought relief programmes, encouraged the unsustainable use of natural resources, contributing to environmental degradation and the perpetuation of poverty (Seely, et al 1995; Dewdney, 1996). Ultimately, the redistribution of productive land, establishing tenure over natural resources, the promotion of labour intensive employment and investment in off-farm options that do not harm the environment should form the focus of poverty reduction strategies in Namibia (Dewdney, 1996).

- The recently-approved (1998) National Drought Policy and Strategy acknowledges the shortcomings of previous drought programmes and seeks to replace short-term, inefficient drought relief with long-term, sustainable drought management (Appendix

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Due to uncertainties regarding the actual climate change impacts; difficulties in measuring the economic value of certain non-market impacts; difficulties in predicting future technological and socio-economic developments; and the possibility of catastrophic events and surprises (WMO & UNEP 1996).
12). Through it, the government has displayed a commitment to reduce Namibia’s long-term vulnerability to drought by promoting several drought mitigation practices. The successful adoption of these practices will contribute to poverty reduction, food security and the sustainable use of natural resources.

- In November 1997, a draft copy of the Integrated Poverty Reduction Strategy for Namibia was circulated for discussion. This policy recognises that, in the long term, the main focus for poverty reduction must come through transforming Namibia from a resource dependent economy to one that manufactures goods and provides services. In the short and medium term, the Poverty Reduction Strategy focuses on the importance of smallholder crop production, tourism, the promotion of small and medium enterprises and the development of labour intensive public works to alleviate poverty.

- In 1996, Cabinet accepted the National Resettlement Policy. The main aim of this policy is poverty alleviation amongst Namibia’s numerous landless and unemployed people through purchasing and reallocating land. Lack of capacity within the MLRR and poor interministerial communication, co-ordination and co-operation currently obstruct the sustainable implementation of the resettlement programme (NAPCOD, 1998).

**Sustainable economic development**

Sustainable economic development remains one of Namibia’s greatest challenges. This is unlikely to occur unless government economic policies and planning are subjected to environmental assessments and natural resource accounts are introduced into national economic decision making (Dewdney, 1996). Another major stumbling block in the achievement of a sustainable future is the lack of coordination between ministries and other stakeholders at the strategic (policy, planning and programme) level (Tarr P. in prep.).

- A National Resource Accounting Programme has been established by the DEA within the MET. Ideally, this Programme will result in an integrated, intersectoral approach to investigating the natural resource demands of different sectors of the economy, and will allow policy makers to plan for economic growth within the context of Namibia’s natural resource constraints. In order to be successful, this programme will require commitment and input from all sectors of Government, not just the MET.

- Namibia’s Draft Environmental Management Act (EMA) should be promulgated by early 1999. This Act will require GRN to integrate environmental concerns at the strategic level. In general this means that environmental issues relating to macro-economic planning and sustainability will be considered in the development of all future policies, plans, programmes and new or revised legislation.

**Population growth**

Namibia’s rapidly growing human population undermines the country’s chances of achieving sustainable development. High population growth rates place increasing pressure on natural resources and increase the vulnerability of Namibia’s future society and economy to the effects of climate change.

- The National Population Policy for Sustainable Human Development (1997) sets out the following targets to counteract population growth:

---

*Namibia’s Vulnerability to Climate Change 3&4 SOCIO-ECONOMIC OVERVIEW*
• **The National Population Policy for Sustainable Human Development (1997)** sets out the following targets to counteract population growth:
  ♦ To reduce the population growth rate to 3.0% by the year 2006 and 2.0% by 2025;
  ♦ To reduce the total fertility rate to 5.0 per woman by the year 2006 and 3.5 by 2015; and
  ♦ To increase contraceptive use from 23% in 1992, to 35% by 2000 and 50% by 2010.

Although this policy recognises some of the impacts of population on Namibia’s future society and environment, it fails to reflect any sense of urgency with which to meet the above-mentioned targets. The policy aims to encourage parents to keep all their children at school, but it fails to emphasise the vital role that the education of girls can play in limiting population growth.

• Population data are vital for predictive studies. The IIASA is currently conducting projects on Population and Sustainable Development in Namibia, Botswana and Mozambique. Vensim software is being used to create systems models for these countries. This project will help to lay an important foundation for future national and regional economic planning and will provide valuable information for future climate change studies.

**Rapid Urbanisation**

Climate change impacts in rural areas are expected to increase rates of urbanisation and exacerbate many of the current stresses placed on the urban poor particularly those that reside in inadequately serviced informal squatter settlements. Possible climate change impacts on these settlements include a decline in water quality, disruptions to food and water supply, increased energy supply problems and increased probability of disease epidemics.

• **In order to address the many problems that currently affect rapidly urbanising areas in Namibia, the National Land Policy (1997)** requires the establishment and proclamation of urban areas as townships or municipalities. This policy advocates support to upgrade informal and squatter settlements, and the close involvement of communities in the administration of these areas. However, in the absence of considerable subsidisation, the former aim is unlikely to be met, as most town councils are currently unable to provide basic services to the non-rate paying areas of their towns. Concerted efforts are being made to improve legislation regarding waste management and hazardous waste control in Namibia (Section 8.5), however it is unlikely to be implemented in the absence of well trained operators and an adequate infrastructure for waste removal and disposal (Tarr, 1997).

**4.3 CONCLUSIONS**

The Natural Resource Accounting Project and shifts in policy are helping to lay a valuable foundation for sustainable natural resource management in Namibia. However, unless poverty is reduced, a growing population will cause continued environmental degradation, and a decrease in the ability of the resource base (water, land and wildlife) to support future generations.
Due to its naturally extreme climatic conditions and a heavy reliance on natural resources, Namibia is highly sensitive to the potential effects of climate change. Populations most likely to be affected are subsistence farmers, the rural poor and communities living in rapidly developing urban settlements with inadequate waste removal and sanitation services.

The nature and success of Namibia’s future economy will be the ultimate determinant of the nation’s ability to cope with the effects of climate change. Low rates of economic growth, high rates of population growth, poverty and ecological degradation will lower the capacity of the country to adapt and will intensify the damage costs of global warming.

**Some Recommendations**

- Enforce stricter population growth control measures.
- Protect vulnerable populations by developing adequate housing infrastructure and extending services (sanitation, safe water supply and waste removal) to informal urban and rural areas.
- Provide education and economic opportunities to upgrade the quality of life of all Namibians.
- Encourage economic diversification, particularly through the creation of alternative income opportunities beyond agriculture.
- Continue to improve natural resource management.
- Factor potential climate change impacts into all of Namibia’s future macroeconomic planning processes.
PART D
VULNERABLE SECTORS

WATER RESOURCES
MARINE RESOURCES
AGRICULTURE
BIODIVERSITY
COASTAL ZONES AND SYSTEMS
HUMAN HEALTH
ENERGY
WATER RESOURCES
WATER RESOURCES

5.1 Hydrology

- Rainfall in Namibia is sparse and displays a high degree of temporal and spatial variability (Section 2.1.1). This leads to a corresponding variability in runoff, soil moisture and stream flow. Of the rain that falls in Namibia, an estimated 83% evaporates and only 2% is available as runoff. The rate of groundwater recharge is very low (1%) and the arid areas (more than half of Namibia) contribute very little to groundwater supplies.

![Hydrological Balance in Namibia](image)

- Water is supplied to consumers from groundwater reserves, perennial surface waters and ephemeral (seasonal) surface water (Fig. 5.1). Water from these sources varies in terms of renewability, quality and reliability and the share of annual water use from each source varies from year to year in response to annual rainfall (Lange 1997). Excluding the water available in the perennial border rivers, the assured annual yield of water for Namibia is estimated to be 500 million m$^3$ /annum (in Day 1997).

5.2 Water Sources

5.2.1 Ephemeral rivers

All rivers that originate within Namibia’s borders are ephemeral. For most of the year they are dry, flowing only briefly with characteristic ‘flash floods’ when enough rain has fallen over their catchment areas. The vegetation that lines the banks of these rivers supply important wood and veldkos (wild edible plants) for communities and fodder for wildlife and livestock in the arid areas of Namibia (Figure 7.2). It is estimated that the livelihoods of approximately 116 000 rural households are dependent on these resources for their survival (Jacobson et al. 1995).

- Large reservoirs, which store seasonal runoff from Namibia’s 12 major ephemeral rivers (Fig. 5.1), have been developed near to Windhoek and other areas of high demand. Dams built in the upper catchment areas of these rivers alter the recharge of downstream aquifers (section 8.3.1). Episodic flooding of the westward flowing
Figure 5.1. Namibia's Main Wetlands

Wetlands

--- Border
--- Perennial River
--- Non-Perennial Drainage Line
--- Ephemeral River or Main Drainage Line

Black text indicates the names of drainage systems and pans
Blue text indicates the names of dams

Pans
Marshes
Springs according to MAWR database
Dams according to MAWR database

Source:
NAMIBIA 1:1,000,000
United Nations, Cartographic Unit
Department of Conference Services
New York

Ministry of Agriculture, Water and Rural Development
Department of Water Affairs

© National Remote Sensing Centre 1997
ephemeral rivers plays an important role in keeping the northward movement of sand dunes in check.¹

- The amount of ephemeral water available for use each year depends on the amount of rainfall. Runoff and river flow depends on rainfall intensity, vegetation interception, infiltration rates and slope of the surface upon which the rain falls. Slow, gentle rains in the ephemeral catchment areas are readily absorbed by the soil, thus recharging subterranean aquifers. Intense storms increase runoff and help to fill storage dams.

### 5.2.2 Perennial rivers

- Approximately 25% of Namibia’s water demand is currently supplied from perennial rivers, all of which originate in neighboring countries and lie near to or form part of Namibia’s international boundaries (Table 5.1). Although these rivers provide the greatest potential water resource they are generally situated far from the areas of highest demand (the city of Windhoek and other main commercial and industrial centres).

- There are no storage dams built on Namibia’s perennial rivers but flow is regulated by dams and water transfer schemes in neighbouring countries. The Ruacana hydropower station on the Kunene River generates varying amounts of electricity for Namibia depending on strength of flow (Section 11.2). A new hydropower scheme is planned for this catchment (Section 11.4).

- Approximately 50% of Namibia’s total population live in the proximity of the northern perennial rivers. The oshana area is the most densely populated in Namibia (an estimated 100 people/km²) and supports approximately 400 000 people (NPC 1997(a)). Although the country’s inland freshwater resources do not contribute directly to the GDP they play a vital role in enhancing the livelihood strategies of at least 100 000 people who derive informal employment and food from subsistence fishing (Box 5.1(a)).

### Table 5.1. Namibia’s main perennial rivers [MAWRD representative pers. comm.]

<table>
<thead>
<tr>
<th>RIVER BASIN</th>
<th>Mean Annual Runoff (million m³)</th>
<th>STATES THAT SHARE THE RESOURCE WITH NAMIBIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kunene</td>
<td>5500 at Ruacana</td>
<td>Angola</td>
</tr>
<tr>
<td>Okavango</td>
<td>10 000 at Mukwe</td>
<td>Angola, Botswana, Zimbabwe</td>
</tr>
<tr>
<td>Zambezi²</td>
<td>40 000 at Katima Mulilo</td>
<td>Angola, Botswana, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe</td>
</tr>
<tr>
<td>Orange</td>
<td>11 000 at Noordoewer</td>
<td>Lesotho, South Africa.</td>
</tr>
</tbody>
</table>

¹ It has been suggested that upstream damming and over abstraction of the Kuiseb and Omaruru rivers has limited their ability to control sand movement. This has led to sand-drift problems in the towns of Walvis Bay and Henties Bay (UCT 1996).
² The other, smaller eastern Caprivi river (Known as the Cuando, kwando, Linyanti or Chobe along its various reaches) originates in Angola and is shared with that country and Botswana.

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Namibia's Vulnerability to Climate Change 5. WATER 38
5.2.3 Groundwater sources

- The water stored beneath ephemeral river courses or in underground aquifers provides essential water for farmers and several towns throughout, and particularly in western, Namibia. Approximately 52% of Namibia’s total water demand was supplied by these sources in 1993 (Lange, 1997). Groundwater extraction is the cheapest available source of water in the country but is highly vulnerable to over-exploitation. Some aquifers in the Namib may be as much as tens of thousands of years old and long since cut off from recharge. Dependence on these sources is obviously unsustainable.

- Groundwater aquifers are finite sources, which can only be recharged by rainfall runoff. Although efforts are being made to improve estimates, no accurate information exists as to the total amount of groundwater that is available in Namibia. This poses a problem for setting rates of abstraction that are sustainable and for assessing the extent to which Namibia may be depleting these sources (Lange, 1997).

5.3 Water Supply

Water is delivered to users via either the bulk water supply or rural water supply agencies. Municipalities, local government/town and village councils also play a role in supplying water to the consumer.

At independence, less than 50% of the rural population had adequate access to a reliable source of safe water (WRI 1998). Consequently, since 1990, the Government has focussed on improving water supply to rural communities. This has involved both the provision of new, and the rehabilitation of existing boreholes as well as the development of pipelines to communities in Caprivi and the Cuvelai area. Recent estimates show that 62% of the population now have access to safe water and that the target for 2007 is 80% (R.Blackie, pers.comm.).

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3 The Rössing mine and the towns of Walvis Bay, Swakopmund, Henties Bay and Arandis are currently dependent on water drawn from underground aquifers in the Omaruru and Kuiseb rivers.
4 One example is the Koichab river aquifer which supplies water to the coastal town of Luderitz. This aquifer contains water that is approximately 7,000 years old. The Koichab river rarely flows these days (Jacobson et al., 1995).
5.4 Water Requirements

Figure 5.1(a) Conflicting Demands for Namibia’s Limited Water Resources

- Irrigation
- Livestock
- Urban and rural domestic use
- Mining
- Fish Processing

LIMITED WATER

- Wildlife and inland fisheries
- Riparian vegetation which supplies essential ecological processes such as water purification, flood control and water storage; grazing, veld kes, construction material and food to rural communities.

5.4.1 Human requirements

- In 1996 an estimated total of 255.5 million m$^3$ of water was supplied to Namibian users through both bulk water supply and rural water supply. Figure 5.2 depicts a breakdown per broad sector of percentage water used and Appendix 4 offers a detailed break down of water use per sector for this period.

Figure 5.2. Use of Water by Broad Sector 1996/1997 [G.M. Lange unpubl.data]
Figure 5.3 depicts state-supplied water consumption by broad economic sector from 1978 to 1993. Estimates of rural water use (i.e. not state-supplied water) for the periods 1980/81 and 1993/94 are given in Appendix 5. Over this period:

- Total water consumption increased at an annual rate of 3.5%;
- Urban consumption increased fastest at a rate of 8.1%;
- Mining consumption which fluctuates with world market demands fell; and
- Irrigation continued to account for more than half of all consumption.

Until recently, water supply was heavily subsidised and the government focused on trying to provide enough water to meet demand. This approach has encouraged the inappropriate and excessive use of water in Namibia (Box 5.1). Affluence and ease of access to water are major determinants of use. Upper income urban households use over 610 litres of water per day (a high value even when compared with users in high rainfall countries) as opposed to low-income households who seldom use more than 70 litres a day (Day, 1997).

Figure 5.3. **Bulk Water Supply 1978 – 1993**

[Source: Dewdney, 1996]

---

*Only water supplied by the DWA*
Box. 5.1 Namibia’s Legacy: Unrealistic Pricing and a Poor Water Ethic [Sources: Dewdney, 1996; Lange, 1997; Day, 1997]

Consumers in Namibia are charged much less than the full cost of water (constituting both operating and capital costs) and total subsidies for bulk and rural supply costs the GRN in excess of N$ 67 million/annum. In 1993 71% of total costs (N$ 37.3 million) were subsidised to users of the bulk water supply. Crop farmers are the most heavily subsidised among these users and pay only 4% of total costs. Until recently, users of the rural supply water scheme (including domestic users and subsistence farmers) received a 100% subsidy from the GRN.

This pricing policy has created a poor water ethic, unrealistic expectations and excessive consumption. It has encouraged financially inefficient and ecologically inappropriate water intensive industries which require significant government subsidies. These include irrigation schemes that have been encouraged by misguided agricultural policies. In one year one hectare of irrigated land can use as much water as 10000 cattle and 1600 rural people. The added value of irrigated produce does not justify the heavy subsidies required.

In 1998 the government transferred responsibility for bulk water supply to NAMWATER, a financially independent parastatal company which aims to phase-in realistic water prices over a 9-year period. Although full cost recovery of water supplied to the rural areas is aimed for, this will be phased in more slowly. This new pricing policy is undoubtedly a step in the right direction with regards to curtailing the unsustainable use of Namibia’s most scarce natural resource.

5.4.2 Environmental requirements

Although water is a fundamental commodity for human well being, industry, and agriculture it is also essential for the maintenance of ecological systems (Figure 5.1(a)). An economic ecosystem evaluation report, estimates that the services and goods provided by the world’s terrestrial wetlands are valued at US$ 4.9 trillion annually (Lindley 1998). Natural wetlands have been identified as Namibia’s most threatened ecosystems. In the absence of sustainable
management of natural water sources and riparian forests, increasing human demands are capable of causing permanent damage to the environment, reducing the livelihood options of rural communities and curtailing future groundwater recharge (Box 5.1(a); Figure 7.2; Section 8.2.2).

Box 5.1 (a) NAMIBIA’S ENDANGERED FRESHWATER FISHERIES
(MFMR 1995; Hay, 1995; Ashley and La Franchi, 1997; Barnard, 1998)

Many communities living in northern Namibia are dependent on freshwater fish in their daily diet for varying periods during the year. Fishing opportunities in the Oshanas rely on sufficient rains falling in the Angolan highlands and are highly episodic. However, in Kavango and Eastern Caprivi, approximately 2 800 tonnes of freshwater fish (estimated to be worth N$1.8 million annually) are caught each year - directly supplying some cash and a valuable supplementary food supply to 79% of rural Caprivians. Although these communities rely on fishing as an important part of their livelihoods, this activity is not yet regulated through legislation.

In recent years more efficient, less sustainable methods for catching fish have been adopted, and floodwaters, which are important for replenishing nutrients and silts as well as for supporting large fish populations, tend to remain on the Okavango floodplain for much shorter periods. Overgrazing is also blamed for the declining health of wetlands and freshwater fisheries in Caprivi where human and cattle population density (especially in the eastern floodplain) is very high. Consequently, many fish species have been identified as endangered.

5.5 The Effect of Drought

- Drought diminishes the amount of surface water available. This places a strain on groundwater reserves which become threatened by overextraction. Emergency boreholes, for example those established during the 1992/93 drought, are usually supplied without forward planning or consideration for the socio-economic and ecological problems they may incur (NAPCOD 1997). Unplanned borehole provision has been criticised for accelerating land degradation (Section 7.2.4) in Namibia.
- Extended periods of drought threaten the ecological sustainability of Namibia’s ephemeral riparian ecosystems (Figure 7.2). Fish stocks diminish during drought years (Ashley and La Franchi 1997).
- During periods of drought reduced access to adequate amounts of clean water threatens the viability of irrigation schemes and results in higher incidences of water borne and waters washed diseases (Section 10.3.2.1).

5.6 Trends and Major Challenges

Almost all southern African countries face the same general challenges with respect to their water sector (Dalal-Clayton 1997). These include:-

- Increasing competition leading to water scarcity and shortages;
- Increasing financial costs of supplying adequate water to rapidly expanding, urbanising populations;
• Increasing pollution which threatens the quality of diminishing water supplies; and
• Permanent environmental damage resulting from the unsustainable removal of water from underground aquifers.

Even in the absence of global warming Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Tanzania and Zimbabwe are all expected to be facing water stress or absolute water scarcity\(^6\) by the year 2025 (van der Merwe 1998; Lindley 1998). Of immediate concern to local hydrologists is the fact that unusually low flow regimes have prevailed in Namibia's ephemeral and northern perennial rivers since the early 1980s (Van Langenhove et al, 1996). Although conditions of low rainfall initially appeared to be the cause, there has been no return to higher flows, even during years of above average rainfall (Box 5.1(b)).

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**Box 5.1(b) FLOW REGIME CHANGES SINCE THE EARLY 1980'S. ARE NAMIBIA'S RIVERS DRYING UP? [Van Langenhove et al 1996]**

Unusually low flow conditions have prevailed in Namibia's perennial and ephemeral rivers since the early 1980's.

- Until 1982 Lake Liambezi in Eastern Caprivi provided important fishing grounds for the local population and was considered to be perennial. It regularly received water from seasonal floods in the Zambezi Basin – either from direct overflow through eastern Caprivi or via backwaters from the confluence with the Chobe River and/or from the Kwanza river. However, Lake Liambezi has received no water from any source since 1982 and by 1985 it had dried out completely.

- No significant floods have come down through the Kwanza River valley since 1982. Flow has steadily decreased and by 1998 had fallen to its lowest ever recorded levels. Vegetation die-off has choked up many of the Kwanza's channels and in 1996 flow into the wetlands in Botswana and Namibia associated with this river, including the Linyanti swamps, were almost completely dry. As a result, drinking water has had to be supplied via tanker services to some local communities.

- Historic low flow events have also been recorded for the Zambezi, Okavango and Kunene rivers since 1982 and have caused water supply concerns, a significant reduction in hydro-power generation from Ruacana and detrimental effects to the important wetlands and ecosystems associated with these rivers.

- Most flow series for Namibia's inland ephemeral rivers display a decline since the end of the 1970's. Average annual inflows into Hardap Dam from the Fish River during the rainy season, have declined by more than 75% since 1977/78. Furthermore, the Kuiseb River has not flowed to the sea since 1963 – an event that used to occur on average at least once every 3 or 4 years.

Hydrologists initially attributed these disturbing trends to temporary conditions of low rainfall. However there has been no return to the higher flows that occurred before, even during periods with above average precipitation. Current speculations include the effects of land-use changes and altered vegetation cover.

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\(^6\) Based on Falkenmarks water scarcity ratings, **absolute water scarcity** occurs in a country where there are more than 1000 people/million m\(^3\) of available water/ year. A country with **water stress** has between 600-1000 people / million m\(^3\) of available water/ year (Dalal-Clayton 1997).

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*Namibia's Vulnerability to Climate Change 5. WATER*
5.6.1 Future Demand

Ultimately, water demand in Namibia is expected to grow due to population growth, urbanisation and income growth. The question is, at what rate? If demand continues to grow at the rate of 3.5% (Section 5.4.1) then water consumption will exceed 300 million m³/year by 2005. If demand from irrigation is allowed to grow at the same rate as the demands from other sectors, water consumption could be as high as 400 million m³/year by 2005. Based on the first estimate Namibia will no longer be self-sufficient in water by 2015 (Ashley, 1995).

Attempts to ensure full cost pricing for water resources in Namibia (Box 5.1) are likely to mitigate these projections in sectors that display a very low economic return on water input (crop farming) but not with others (mining, fish processing, and tourism) that generate relatively high returns (Table 5.3). Commercial irrigated agriculture accounts for approximately 30% of the total water consumption in Namibia but is responsible for the lowest sectoral output per m³ of water input.

It is predicted that domestic use will be curtailed by the new water prices. Future water demand is discussed in more detail in Section 5.8.2.2.

Table 5.3. Water Use and Returns for Namibia’s Economic Sectors [Sources: CSO 1996; Lange 1997]

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>VALUE(^7) per m³:1993 (NS)</th>
<th>Value added per m³ of water input (NS)</th>
<th>% of water use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial crops</td>
<td>&lt; 0.20</td>
<td>Na</td>
<td>32.0</td>
</tr>
<tr>
<td>Commercial cattle</td>
<td>26.20</td>
<td>4.70</td>
<td>11.0</td>
</tr>
<tr>
<td>Communal agriculture</td>
<td>5.00</td>
<td>4.50</td>
<td>17.0</td>
</tr>
<tr>
<td>Diamond mining</td>
<td>83.60</td>
<td>44.7</td>
<td>5.32</td>
</tr>
<tr>
<td>Other mining</td>
<td>91.70</td>
<td>32.0</td>
<td>4.54</td>
</tr>
<tr>
<td>Hotels &amp; restaurants(^8)</td>
<td>258.70</td>
<td>112.7</td>
<td>0.47</td>
</tr>
<tr>
<td>Non fish manufacturing</td>
<td>345.70</td>
<td>79.60</td>
<td>1.88</td>
</tr>
<tr>
<td>Fish processing</td>
<td>757.10</td>
<td>451.70</td>
<td>0.31</td>
</tr>
<tr>
<td>Transportation</td>
<td>871.80</td>
<td>315.10</td>
<td>0.31</td>
</tr>
<tr>
<td>Other services</td>
<td>1317.70</td>
<td>739.60</td>
<td>1.41</td>
</tr>
</tbody>
</table>

As there are huge disparities in the amount of water required to produce different crops and meats, it is becoming essential for many countries, particularly those in

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\(^7\) The value of water means the NS produced per m³ of water used.
\(^8\) Tourism indicator
arid and semi-arid areas, to consider agricultural options that display some degree of drought resistance.

5.6.2 Cost and Availability of Water
In Namibia the two main issues of immediate concern are the future availability of water and the financial cost of supply. Current water supply to the central area of Namibia, including the city of Windhoek, has almost reached a point where it can no longer meet growing demand (Box 5.2). In addition a lack of water has prevented development in many towns. Thus, it has become essential for the GRN and municipalities to begin to enforce stricter water demand management policies (for example, more realistic pricing) together with investigating the possibility of developing new water sources. The latter include:

- Desalination of seawater and brackish groundwater (Walvis Bay, Swakopmund and Henties Bay are expected to be receiving desalinated water by 2003).
- Extending the Eastern National Water Carrier to the Okavango River to meet the demands of the central water management area (Box 5.2).
- Sinking more boreholes, mainly to meet rural demand.
- Building new dams.

Other possibilities to augment available water and some water demand management strategies that are being considered include:

- Reallocating water from irrigated crop production to other sectors.
- Re-using water from industry or irrigation, treating effluent to potable water standards and the substitution of potable water used in industrial processes with more brackish water.
- Encouraging the increased efficiency in use of current sources.

Both the Kunene and the Okavango rivers rise in Angola, a country suffering from many years of civil war. As living standards and industrial and agricultural development improve in a more peaceful Angola, that country’s demand for water is expected to increase dramatically. Consequently, less water might arrive at the Namibian border from these rivers in future.

The appropriateness of new sources needs to be carefully investigated with respect to potential social, financial and environmental costs they are likely to incur. Table 5.4 offers a broad summary of the likely constraints expected for some of Namibia’s new water source options. Whatever choices are made, the cost of supplying water to the country’s growing population will increase considerably in decades to come. Increased transaction costs, associated with increased need for negotiations in order to share dwindling resources within SADC, are also expected (B.de Bruine pers comm).
Box 5.2 THE IMMEDIATE CHALLENGE: SUPPLYING WATER TO NAMIBIA’S CENTRAL AREA [Source: the Okavango Pipeline Feasibility Study, Ben Groom pers. comm.]

Water supply to the central area of Namibia, including the city of Windhoek, is rapidly reaching a critical point. The Figure below offers three demand predictions and their relationship to future supplies.9

WATER DEMAND PREDICTIONS vs POTENTIAL FUTURE SUPPLY FOR THE CENTRAL AREA OF NAMIBIA.

DEMAND
1. The MIDDLE CAWMP (Central Areas Water Master Plan of 1993) demand prediction estimates an average growth rate of 4.68% per annum. Based on this prediction water for the central areas would be depleted by now without input from additional groundwater supplies.
2. The LIKELY demand is a more recent prediction and is based on a constant growth rate of 2.28% per annum.
3. The WDM demand bases its prediction on the assumption that the new water demand management policies which involve more realistic pricing of water, will result in a 25% reduction in the growth rate of water demand. This projection takes a constant growth rate of 1.71%.

SUPPLY
1. The POTENTIAL SUPPLY of water for Namibia’s rapidly growing central area consists of :-
   a) 95% assured yield from the von Bach, Omatako and Swakopport dams (20.38 mill.m²/year).
   b) Groundwater extracted from the Windhoek, Tsumeb, Platveld, Grootfontein and Otjiwarongo aquifers (24.55 mill.m²/year).
   c) Output from reclamation works in Windhoek (7.6 mill.m²/year).
      Total = 56.53 mill. m²/year
2. In addition, approximately 34 mill. m²/year is estimated to represent the untapped future sustainable yield from the underground aquifers. This represents the PLUS GROUNDWATER SUPPLY value.10
3. If it is feasible to extend the ENWC to the Okavango River, a further 20 mill. m²/year will be made available.11

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9 This figure makes the assumption that potential water supplies will always be constant. It makes no allowance for altered supplies due to climate change or increased demands from neighbouring countries on the Okavango River.
10 This value is an estimate as the exact sustainable yield of groundwater is difficult to ascertain.
11 Water managers originally hoped that 120 mill. m²/year could be pumped from the Okavango. It is now clear that this may incur severe environmental impacts on the Okavango Swamps in Botswana and most recent reports indicate that 20 mill.m²/year is a more likely figure. The Okavango pipeline plan has not been finalised and has received opposition from southern African environmentalists and NGO’s. Desalinated water piped up from the coast is expected to be very expensive and is not included as an option here.

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5.6.3 Water Quality

- General water degradation trends in Namibia are summarised in Table 5.5. Growing urbanisation and industrialisation is likely to lead to increased water pollution levels both within Namibia and neighbouring countries.
- Human health is strongly linked to access to adequate amounts of clean water. Water borne, water washed and water-based vector diseases are discussed in more detail in Chapter 10.
- Rivers in southern Africa are shared resources and their pollution is cause for mutual concern. Improved pollution monitoring and stricter enforcement of pollution control legislation is essential throughout the region (Dalal-Clayton, 1997).
- Increased salinisation of coastal aquifers is likely as sea-levels rise (Section 9.3).

5.7 Current Policy and Action

Namibia is in a transition period regarding the management of its diminishing water resources. In the past, legislation and policy made no reference to sustainable use and focused only on meeting demand.

- Main targets for the water sector as set out in NDP1 include:
  - Maintaining current levels of urban access to potable water (i.e. >95%)
  - Achieving 80% rural access to potable water by 2007.
  - Establishing 50 new rural water points a year.
- Through its Water Supply and Sanitation Policy (WASP) the GRN recognises the need for managing water demand through more realistic pricing, water efficiency methods and the prioritising of use. The establishment of NAMWATER (Box 5.1) has set the wheels in motion towards meeting some of these goals.
- Water resource managers are beginning to recognise that water is an economic resource of high value and the NRA project initiated by the DEA has begun to construct NRA’s for the water sector. These efforts will go a long way towards assisting in the design of future development strategies that are financially and environmentally sustainable.
- In order to improve co-operation between rural communities and water supply authorities shared control and ownership over water resources has been encouraged through the establishment of regional Central Water Committees and local Water Point Committees.
- Namibia’s Environmental Assessment Policy calls for integrated planning to assure that benefits from water use are maximised and negative impacts are minimised. In particular, water, agricultural and land-use policy need to be planned jointly in order to reduce current and prevent future conflicting interests (Box 7.2).

The White Paper on Freshwater Fisheries (1997) lays a foundation for a new Freshwater Fisheries Act. It aims to ensure long term food security to rural riparian populations through adopting a sustainable approach to the exploitation of fish resources.
Table 5.4 The Environmental and Financial Costs of Developing New Water Sources in Namibia [Booth et al 1994; Dalal-Clayton 1997; Day 1997; Lange 1997].

<table>
<thead>
<tr>
<th>Interbasin water transport schemes</th>
<th>Dams</th>
<th>Desalination Plants</th>
<th>Boreholes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural community in the Cunene area receive water from a pipeline extending from the Caluseque dam in Angola. The ENWC is incomplete and requires a stretch of 250 km of pipeline to be extended to the Okavango River where it will extract 20 mil, m³/year. When complete the ENWC will consist of 3-5 major aquifer systems, 550 km of pipeline and 200 km of open canals.</td>
<td>At present Namibia has 12 dams on ephemeral rivers. An estimated 10 000 small dams harness between 3 000 and 50 000 m³ of runoff, a high proportion of which is used for small-scale irrigation and livestock. The development of a large dam on the Kunene has been proposed to make Namibia self-sufficient in energy production. A large dam is also being investigated on the lower Orange River.</td>
<td>By 2005 Walvis Bay, Swakopmund, Rössing Mine and Lüderitz are likely to receive desalinated water.</td>
<td>An estimated 31 850 boreholes existed in Namibia in 1995. Many are privately owned and not all are functional. Groundwater taken from hand dug wells or pumped from drilled boreholes supplies approximately 40% of Namibia’s human population with water.</td>
</tr>
</tbody>
</table>

Financial Costs

| Completion of the ENWC will cost an estimated N$ 600 million (1996 prices). The unit cost of pumping water to Windhoek via the ENWC is estimated at N$5.17/m³ (1996 prices). | Dams on ephemeral courses are expected to cost between N$ 20 million and N$ 40 million to build. The proposed dam to be built on the Kunene River is likely to cost an estimated N$2 5 billion, but this is primarily for electricity production. | The current estimated cost of supplying coastal towns with desalinated water is approximately N$ 6-8/m³. Supplying desalinated water to the Windhoek area is an estimated N$12-13/m³. The desalination process requires large amounts of energy. | Installation costs vary between N$100 000 - N$200 000 depending on the geology of the area and the power source for the pump. Boreholes demand regular maintenance. |

Environmental costs

| Once in operation the ENWC could cause significant environmental impacts to the Okavango delta in Botswana. The 200 km of open canal poses a constant threat to wildlife. The danger of genetic pollution, species displacement and the spread of alien invasive organisms need to be investigated. | Large dams can be significant emitters of GHG’s. Dams disrupt downstream ecological functioning and floodplain dynamics. If built in the upper catchments of ephemeral rivers, dams decrease the amount of water available to downstream users and riparian habitats. Dams can aid the spread of alien invasive organisms and during droughts, can increase the spread of water borne diseases. | The environmental impacts of highly saline warm water being pumped back into the sea as a result of the desalination process still require investigation. | The establishment of permanent water points in areas only suitable for seasonal use has encouraged the development of unplanned permanent settlements and overgrazing. This contributes to desertification. Overdevelopment can cause negative impacts on downstream users (ecosystems and human settlements) and increase soil salination. |

| Comments | The viability of dams is threatened by reduced capacity through siltation (as a result of soil erosion) and unpredictable levels during dry seasons and drought. High evaporation rates limits the efficiency of dams in Namibia (on average 25% as a ratio of the river flow) | The cost of pumping water up to Windhoek and other parts of the central plateau from the coast could be equivalent to about 34% of government spending for 1997. | Groundwater recharges extremely slowly. The environmental and social impacts of boreholes are seldom considered prior to their installation. |

12 Two sites are being investigated for this dam. One at the scenic Epupa Falls and the other in the area of the Baines Mountains.

13 For example, the proposed Brückmoro and Khan River dams.

14 For example the proposed dams on the Ugab River (at Zebra Kop) and on the Kunob River (at Donkerkraal).
Table 5.5 Trends in water resource degradation in Namibia  
[adapted from Dewdney, 1996; Day, 1997; Köhler, 1997; Lange, 1997].

<table>
<thead>
<tr>
<th>DEGRADATION</th>
<th>TREND</th>
<th>Proximate/direct cause</th>
<th>Ultimate/indirect cause</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowering of water tables(^{16})</td>
<td>Deteriorating</td>
<td>The possibility of unsustainable abstraction of groundwater; irrigation of crops (^{17}); upstream dams; soil degradation.</td>
<td>Aridity; growing population; increased water demand.</td>
<td>Increased vulnerability to drought; damage to water quality, ecosystems and rural livelihood strategies. Loss of wildlife and tourism potential.</td>
</tr>
<tr>
<td>Decreasing surface waters</td>
<td>Expected to deteriorate rapidly</td>
<td>Dams and abstraction for water transfer schemes within the region.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WATER QUALITY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticides</td>
<td>Roughly constant</td>
<td>Mosquito control; irrigated crop pest control.(^{18})</td>
<td>Malaria, Sleeping Sickness; control of crop pests.</td>
<td>Long term eco-toxocological effects which threaten ecosystem and human health.</td>
</tr>
<tr>
<td>Fertilisers(^{19})</td>
<td>Increasing</td>
<td>Agricultural enhancement</td>
<td>The need for increased food production.</td>
<td>Eutrophication. Disturbed nutrient cycling.</td>
</tr>
<tr>
<td>Salinisation</td>
<td>Increasing</td>
<td>Irrigation(^{20}); abstraction of water from surface aquifers</td>
<td>Aridity; growing population.</td>
<td>Damage to water quality, ecosystems and rural livelihood strategies.</td>
</tr>
<tr>
<td>Disruption of drainage into Oshanas</td>
<td>Has occurred</td>
<td>Roads and canals; irrigation schemes in Angola.</td>
<td>Lack of coordinated planning.</td>
<td>Disrupted flow, less water available for groundwater and soil fertility replenishment.</td>
</tr>
<tr>
<td>Decline in Riparian Vegetation</td>
<td>Increasing</td>
<td>Grazing livestock; use of trees for fuel, construction, carving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Declining fish populations</td>
<td>Increasing</td>
<td>Overfishing; use of modern equipment; damaged wetland habitats; reduced water availability.</td>
<td>Growing population and poverty leading to an unsustainable increase in the use of resources; loss of traditional management practices; lack of education.</td>
<td>Damage to ecosystems and rural livelihoods.</td>
</tr>
<tr>
<td>Floodplain degradation</td>
<td>Increasing</td>
<td>Deforestation; crop cultivation; over-grazing and stock trampling</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{16}\) Unsustainable removal from the Omaheke, south Kunene and Erongo water tables and the Kuiseb and Omaruru rivers is already believed to be occurring.

\(^{17}\) Particularly in the Karas area (Maize Triangle) and the Omaruru and Swakop river catchments.

\(^{18}\) An estimated 20% of the agrochemicals and fertilisers used by farmers in the Hardap Dam area are washed into the Fish River basin from where it is seasonally flushed into the Orange River (Köhler 1997).

\(^{19}\) In order to make the 560 Ha of land that are placed under irrigation along the Okavango river financially viable, it is necessary to use 750 kg of fertilisers per Ha per annum. Fertilisers and other agrochemicals infiltrate the groundwater in the Karas area (Maize Triangle) (Köhler 1997).

\(^{20}\) Particularly in the Swakop River valley, Stampsriet and Hardap Dam areas.
• The sustainable management of water transcends national boundaries and co-ordinated planning between southern African countries is essential for future management (Lange, 1997). Namibia is the end user of both the Kunene and the Orange Rivers and, in order to secure a reasonable and equitable share of these waters, the GRN has entered into several agreements with other SADC states (Appendix 7).

5.8 Vulnerability of the Water Sector to Climate Change

Water demand worldwide has tripled in the last two decades as a result of growing populations, increased affluence and the heavy water requirements of certain forms of agriculture. In future decades, climate change is expected to aggravate the potential global water crisis, even in countries that are water rich (Pearce, 1997c).

5.8.1 Climate change scenarios

• Changes in runoff by the 2050’s predicted by Hulme’s 3 scenarios, are displayed in Figure 5.6. The ‘core’ scenario suggests:
  ♦ decreased runoff of between 20–40% over most of Namibia as a result of lower rainfall and higher rates of evaporation (Section 2.5.2);
  ♦ decreased runoff of between 10-20% for Caprivi;
  ♦ an increase of up to 10% in runoff in north-central Namibia.
  ♦ an increase in year-to-year runoff variability over most of southern Africa.

• Palaeoclimatic trends from South Africa suggest that during warming episodes in the Holocene period (5450 - 4120 years BP), more extreme floods occurred (Zawada et al, 1998). Thus, despite overall runoff decreasing, global warming could be accompanied by more extreme flood events during good rainfall years.

5.8.2 Climate change impacts

The Namibian water resources sector is plagued by drought, increasing demand and diminishing supplies (section 5.5). Under climate change conditions, current constraints are likely to be greatly exacerbated ultimately affecting human health, agricultural output, inland fisheries, energy supply, riparian vegetation and wildlife populations (Figure 5.4). Potential climate change impacts to the water resources sector are summarised in the following sections.

5.8.2.1 Biophysical Impacts

Hydrological Resources

• Runoff, river flow, and thus water availability will be affected by changes in precipitation, evaporation and transpiration. Although it is uncertain exactly how changes in temperature will impact on regional rainfall distribution and intensity, Glantz (1992) suggests that a 1°C - 2°C increase, if accompanied by a 10% reduction in precipitation, could result in a 40% - 70% reduction in annual runoff. Currently, 83% of Namibia’s rainfall is estimated to be lost to evaporation (Figure 5). Any increase in this amount due to increased temperatures will place tremendous strain on Namibia’s water resource sector.
**Figure 5.4 Potential impacts of climate change on Namibia’s water resource sector**

[Author’s compilation]

Hydrological Resources continued.
In parts of Angola where rainfall is currently high, Hulme’s ‘core’ and ‘dry’ scenarios suggest decreases in runoff of up to 20% (Figure 5.6). This will affect runoff into Namibia’s northern perennial rivers and consequently impact on water-supply schemes and output from current and future hydroelectric power plants (Section 11.5). On the other hand, the ‘wet’ scenario suggests a general increase in runoff – particularly in the north-central and north-eastern areas of Namibia and over the perennial river catchment areas in Angola and Zambia (Figure 5.6). However, this scenario contradicts recent hydrological observations that show a considerable decline in the flow regimes of both perennial and ephemeral rivers in Namibia since the early 1980’s (Box 5.1(b)).

**Water Quality**
- Higher temperatures (which reduce the dissolved oxygen content in water bodies) and reduced stream flow due changes in precipitation and evaporation will cause a degradation in water quality.
- Coastal aquifers are vulnerable to salt-water intrusion due to sea-level rise (Section 9.3).
- Reduced rainfall runoff will result in lower streamflow and increased concentrations of pollutants in perennial rivers. In addition, certain climate change effects (e.g. increased agricultural pests and vector borne diseases – see Sections 8.6.1.2 and 10.3.2) are likely to result in an increase in the use of pesticides, agrochemicals and other pollutants that accumulate in streams and rivers.
Figure 5.6. Average annual runoff using 1961-90 climate and percent change in average runoff by the 2050s decade under 3 climate change scenarios [Hulme et al 1996].

1961-90 annual runoff (mm)

Change in annual runoff (%)
"core" scenario – UKTR2050

"dry" scenario – CCC2050

Change in annual runoff (%)
"wet" scenario – OSU2050
5.8.2.2 Socio-Economic Impacts

Water Demand
Climate change will affect the availability and cost of water supply. This has the potential to influence demand and agricultural (irrigation and livestock), industrial and energy output. Domestic and commercial use will also be affected as the cost of water increases in order to curtail overuse. Some expected projections are considered below.

- **Agriculture** as a whole is predicted to grow at a rate of 3% - 5% between 1998 and 2017 (Table 3.2). However, it is assumed that water demand for this sector will grow at a far slower rate or not at all. This assumption is based on the likelihood that new pricing and other changes in policy will favor a shift towards more water-efficient higher value crops. Under climate change scenarios crop production in some areas may even improve as a result of enhanced water use efficiency and other effects of CO₂ ‘fertilisation’ (Box 7.5).

It is further assumed that in future decades commercial cattle will be reduced to numbers that are far better suited to the country’s rangeland and climatic conditions and will, as a result, produce a higher quality of beef. Water demand from the livestock sector will be further curtailed by the possible increase in game farming²¹. However, although the demand for water may not necessarily increase for this sector, changes in rainfall due to global warming are likely to reduce the carrying capacity of Namibia’s rangelands (Table 7.1) and this could dramatically affect output and water demand from agricultural activities.

- **Industry.** Fish processing is expected to grow by at least 5% per annum (Table 3.2). As it has a high economic return on water input, it is unlikely that water demand for this sector will be curtailed by future increases in water price. The effects of climate change on water demand for this sector are likely to be minimal as desalinated water will be used in future fish processing.

Meat processing may grow at a rate of 2-4% per annum (Table 3.2). As this sector also has a high economic return on water input water demand is expected to grow accordingly. In future, altered agricultural output and increased water pricing due to the effects of climate change could constrain demand for water from this sector.

- **Mining.** The only major source of growth expected within this sector during the next 20 years is from the proposed Skorpion Zinc Mine near Rosh Pinaar (Blackie

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²¹ Game species generally utilise water more efficiently than domestic stock – displaying lower drinking frequency and consuming less water per day. (Auer, 1998).
1998). Water for this operation will be piped 45 km from the Orange River and demand is estimated at 4.38 Mm$^3$ per annum (DEA representative, pers comm). Climate change conditions could severely affect water availability from the Orange and thus output from this mine, particularly as other development projects (e.g. the Lesotho Highlands Water Scheme) are likely to cause alterations in future flow. Current threats to the Ramsar wetland at the Orange River mouth will be exacerbated.

- **Domestic demand.** The rate at which household water demand will grow depends on population growth rates, rates of urbanisation and future levels of affluence (Part C). The new pricing policies are likely to limit future demand from urban households. Under climate change conditions even higher water pricing and water restrictions are probable. This will affect the cost of locally produced goods and services and further curtail domestic demand.

### Public Health
Access to adequate amounts of clean water is an essential determinant of public health. Decreasing water availability and quality resulting from an altered rainfall regime under climate change conditions could create water supply problems to rural and urban settlements. This is likely to affect infant mortality and under five-year-old death rates and the prevalence of water-washed and water-borne diseases (Chapter 10), especially amongst the urban poor and communities living in isolated rural areas.

### Regional conflict
Many countries within SADC are facing water stress (Section 5.6). Although the region is presently moving towards political security, it is impossible to forecast whether this position will continue (Dalal-Clayton 1996). The trend towards more frequent and severe droughts within the region is likely to increase competition over limited water resources. This has the potential to cause future conflict within the region.

### Water Management
In addition to the social, environmental and financial costs depicted in Table 5.4, Namibia's water managers must begin to consider and plan for the potential affects of climate change on established and proposed water sources and storage facilities.

- **Desalination Plants.** The effects of sea-level rise (Table 9.2) will have to be considered when designing the facilities for this alternative water source. Desalination requires large amounts of energy input. Thus, the future cost and availability of electricity under climate change conditions will influence the future cost of the desalination process.

- **Pipelines and water transfer schemes.** In addition to the possibility of reduced water availability from the Okavango, Kunene and other perennial sources, warmer conditions will increase the evaporative demand from the open parts of the ENWC and other water transfer schemes.
• **New boreholes and dams.** The combined effect of reduced rainfall runoff due to global warming and increased numbers of dams and boreholes on ephemeral river catchments, will be highly detrimental to Namibia’s vulnerable underground aquifers (Tables 5.4 and 5.5).

Dams have enabled the development of urban areas and agriculture in Namibia. However, they seriously alter the frequency of river flow and runoff patterns. For example, 10 Mm³ of flow is required for the Kuiseb River to reach Rooibank and to recharge coastal aquifers. Results from a yield analysis of the proposed Donkersan dam on the Kuiseb catchment show that if this dam is built, then the number of years with a flow of 10 Mm³ or more would fall from 1 out of 2.1 to 1 out of 7.9 (80% yield extracted) (Mostert, 1998). In addition to threatening the recharge rates of underground aquifers, dams are capable of affecting downstream riparian ecosystems, the livelihoods of communities (for example, the Topnaar communities in the lower reaches of the Kuiseb River) and causing a reduction in wildlife and tourism potential. Under scenarios of reduced rainfall and runoff, these impacts are likely to be magnified considerably – particularly as new dams are becoming increasingly necessary in order to meet Namibia’s growing demand for water.

MAWRD hydrologists have begun to consider reduced rainfall scenarios as a possible result of climate change in their routine modelling of ephemeral river catchment areas where future dams may be built. The first investigation to incorporate scenarios with projected reduced rainfall figures is a dam yield evaluation study for upper catchment areas on the Kuiseb River. This study highlights the non-linear relationship between rainfall and runoff - whereby a decrease in precipitation produces an exponentially larger decrease in runoff and dam yield (Appendix 7(a)).

Nevertheless, more than just reduced rainfall volume must be considered when trying to assess the effects of climate change on the country’s water resources and storage facilities. The possibility of greater spatial and temporal rainfall variability will mean a less reliable source of water in future. In addition, increased air temperature will decrease the amount of water available from runoff and increase the evaporative demand from dams.

**5.9 Conclusions**

Namibia is the driest country within a drought prone region and the scarcity of water currently limits the development of virtually all sectors. Implementing strategies to provide a sustainable water supply to the country’s agricultural sector and rapidly expanding, urbanising population, remains Namibia’s biggest challenge. Furthermore, increased demand from groundwater and some surface water resources are liable to cause serious ecological problems in the future.
Most scenarios for the SADC region suggest reduced rainfall runoff and increased rainfall variability under climate change conditions. Together with increased temperatures, these altered conditions have the potential to dramatically compound current constraints relating to water availability, quality and cost of supply. Recent changes in water management policy, particularly those relating to more realistic water pricing and efforts to coordinate planning and management at a regional level, provide essential adaptation measures which will go a long way towards helping to ensure a sustainable future for the country’s diminishing water resources. Undoubtedly, these measures, in addition to improved pollution control and drought contingency planning, will have considerable net benefits independent of climate change. Nevertheless, it is essential that an in-depth assessment of the impacts of global warming on Namibia’s future water resources begin as soon as possible. Only once this is complete, can the potential biophysical and socio-economic impacts of reduced water availability and increased cost of supply begin to be factored into Namibia’s future macroeconomic planning processes.

**Some Recommendations**

- Ensure that there is a continuous change in policy encompassing changes from supply management to demand management.
- Improve intersectoral communication and encourage the joint planning of water, agricultural and land-use policy in order to prevent future conflicting interests.
- Continue to revise tariff structures to reflect the true economic value of water.
- Improve the quantitative and qualitative monitoring of water resources so that the possible effects of climate change can be detected and planned for.
- Assess changes that might need to be made to institutional frameworks to ensure adaptability to possible climate changes.
- Limit the effects of current variability of runoff and high potential evaporation as much as possible. Ensure that future dams are designed to reduce evaporation as much as possible and that more efficient hydropower turbines are utilised. Where possible replace all open canals with closed conduits.
- Continue to improve water resource management on a regional basis within SADC.
- Increase public awareness of the country’s severe water constraints. Encourage the use of water-efficient toilets and appliances, recycled water for non-potable uses, arid adapted gardening, the reuse of purified effluent for irrigation of sports fields, parks and cemeteries.
- Introduce low water use and high value per water use crops, practice night-time irrigation, convert irrigation systems to drip, micro spray.
- Protect riparian vegetation and wetland ecosystems in order to help ensure future water purification, streamflow regulation, nutrient recycling and the sustainability of the inland fisheries sector.
MARINE RESOURCES
MARINE RESOURCES

6.1 Namibia’s Marine Resource Base
The country’s marine resources (Figure 6.2) form part of the Benguela ecosystem, which is characterised by one of the most intense upwelling systems in the world (Section 8.2.3). Although the species diversity of the Benguela is low, the system produces large volumes of plankton, which in turn support vast populations of commercially exploitable pelagic and demersal fish species. Higher predators such as seals, dolphins and seabirds also thrive in the Benguela’s cold waters. Both the marine fisheries and mining sectors are very important foreign exchange earners and significant employment generators for Namibia.

6.2 Environmental Threats and Challenges
Seasonal red tides, sulphur eruptions, oxygen deficiencies and episodic Benguela Niños, are all extreme natural events that impact heavily on the living marine components of the ecosystem (Box 6.1 and Figure 6.1). These events are largely triggered by meteorological factors and, although fisheries research and environmental monitoring capacities are improving, the inability to forecast the regional and global climate changes that cause these environmental fluctuations constantly challenges this sector (Section 6.3). In addition to the natural variability of the ecosystem, threats to the productivity of Namibia’s marine fisheries sector include the over exploitation of stocks and other human activities (Figure 6.1 and Section 9.1).

Figure 6.1 Threats to Namibia’s marine fisheries sector.
Pelagic fishing industry
- pilchard, anchovy, juvenile horse mackerel.

Midwater horse mackerel fisheries
- Demersal Fish
  - hakes, monkfish, kingklip, west coast sole.

Commercial line fisheries and recreational angling
- Albacore tuna, big eye tuna, snoek, kob, west coast steenbras, barbel, galjoen blacktail.

Deep sea fish stocks
- Alphonsino, orange roughy, oree dory.

Rock lobster fishery

Deep sea crab fishery
- Deep sea red crab

Small scale mariculture
- Pacific oysters, European oysters, black mussels, seaweed, rock lobster.

Cape fur seals

- Coastal zone developments
  *Industrial* - canning and fish meal factories (Walvis Bay), rock lobster factories (Lüderitz), salt works (Swakopmund and Walvis Bay) and guano collection.

- Planned upgrading of the Walvis Bay and Lüderitz harbours.

- Tourism growth points - Swakopmund, Henties Bay, Walvis Bay and Lüderitz.

Desalination plant
- To be located near Swakopmund, Operational by the year 2003.

- Offshore oil and gas exploration
  - Large reservoirs of dry gas (the Kudu field) have been found in the region of Oranjemund. Prospecting for oil continues.

Marine diamond mining
- Coastal open cast mining, subtidal mining, deep-sea mining.
Natural environmental variability is considered to be the most important determinant of interannual fish stock variation in Namibia.

The upwelling process, which forces cold bottom water (rich in nitrates and phosphates) to the upper layers of the sea where phytoplankton can thrive, thus triggering the Benguela's productive food chain, is dependent on Namibia's prevailing southerly winds and the northward flowing Benguela current. During periods of upwelling the ocean becomes cooler, water circulation is more energetic and oxygen levels rise with increased mixing and current movement. Seasonal and other changes in the South Atlantic high-pressure system cause variations in the wind regime which in turn influence the rate and intensity of upwellings. Plankton production, fish migrations, spawning and egg and larval survival all respond to these changes.

In the central and northern Benguela Current region southerly winds tend to be at their strongest in winter and spring, although hot easterly and northerly winds blowing off the desert are periodically capable of suppressing upwelling during these periods. In summer and autumn the prevailing southwesterly winds slacken and Benguela upwellings are naturally suppressed. The warmer waters enhance the production of plankton but, as a result of less energetic water circulation, their organic decay can sometimes result in lowered oxygen levels near the seabed, periodic sulphur eruptions and red tides. These phenomena are capable of causing heavy mortalities of near shore marine life along the Namibian coast.

Although suppressed upwelling and oxygen deficiency in shelf bottom waters are a natural feature of the Benguela during the summer months, these conditions periodically prevail for much longer periods, disrupting normal distribution patterns of fish and sometimes causing dramatically increased mortalities of commercially viable species. The environmental conditions that drive these episodic warm water events appear to originate in the tropical east Atlantic and have been loosely termed Benguela Niños. They are characterised by a widespread slackening of the prevailing southerly winds followed by extensive intrusions of warm Angola Current water southwards and reversals in surface currents. The warmer waters, although generally resulting in suppressed stocks, have been known to enhance the wider distribution and spawning of economically less valuable species like Horse Mackerel. Concurrent with Benguela Niños there appear to be more frequent and widespread red tides and increased possibility for sulphur eruptions. The most dramatic example of increased mortalities due to unexpected environmental conditions occurred during the Namibian summer of 1993-1994 when an estimated 2 billion Cape hake recruits (about 50% of the juvenile hake population) were trapped by unusually severe and exceptionally widespread anoxia in shelf bottom waters in the northern Benguela.

There is evidence to suggest that global populations of fish fluctuate synchronously, in phase with certain climatic signals. Environmental anomalies in the Benguela Current system sometimes lag El Niño events by a year and recent observations suggest that ENSO teleconnections between the Pacific and Atlantic are probable. Higher rainfall is sometimes experienced over the Namib desert during Benguela Niño years and lower than normal air temperatures are recorded inland during the winter months.

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1 Bottom topography and seaward extent of the continental shelf also influence upwelling. The most intense upwellings occur off Cape Frio, Palgrave Point, Conception Bay and Lüderitz - areas where the shelf is narrowest and the wind strongest.
2 Red tides occur when marine algal cells multiply rapidly or "bloom". Mortalities of crustaceans and fish result either from the neurotoxins produced by the blooms or due algae clogging up fish gills. Consuming shellfish that have been affected by harmful algal blooms can cause severe cases of paralytic shellfish poisoning and occasional death in humans (M.O.'Toole, pers. comm.).
3 For example, the severe floods of 1934 and 1963 (Bakun 1998).
6.3 Current Trends

- After Independence improvements were made regarding the monitoring and regulation of fish stocks. A 200-mile exclusive economic zone (EEZ) was declared, prohibiting fishing by foreign trawlers except under licence. The GRN also set conservative Total Allowable Catches (TAC’s) to try and ensure the sustainability of resources and to enhance the recovery of anchovy, pilchard and hake stocks after decades of overexploitation.


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<tr>
<td>NS mill.</td>
<td>500</td>
<td>643.9</td>
<td>857.0</td>
<td>1094.6</td>
<td>1284.3</td>
<td>1405.3</td>
<td>1373.9</td>
<td>1700.0</td>
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<tr>
<td>NS/kg</td>
<td>1.25</td>
<td>1.09</td>
<td>1.31</td>
<td>1.38</td>
<td>1.98</td>
<td>2.47</td>
<td>2.66</td>
<td>3.21</td>
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<tr>
<td>Total value of exports N$mill.</td>
<td>487.5</td>
<td>631.0</td>
<td>838.8</td>
<td>1074.1</td>
<td>1259.5</td>
<td>1372.9</td>
<td>1348.8</td>
<td>1600.0</td>
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<tr>
<td>% of total exports (by value)</td>
<td>14.0%</td>
<td>13.2%</td>
<td>17.6%</td>
<td>21.3%</td>
<td>23.7%</td>
<td>25.1%</td>
<td>19.2%</td>
<td>22.3%</td>
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<tr>
<td>Estimated % contribution to GDP (fishing and fish processing)</td>
<td>5.2%</td>
<td>4.6%</td>
<td>6.3%</td>
<td>8.2%</td>
<td>8.8%</td>
<td>8.7%</td>
<td>6.3%</td>
<td>7.3%</td>
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- The marine fisheries sector has grown rapidly since 1990. In terms of economic performance output doubled from 1990 to 1993 and since then, despite a 35% drop in landings, has remained roughly constant (Table 6.1). Reasons given for this trend include:-
  ♦ The targeting of new deep-sea species (mainly Orange Roughy and Alfonsino);
  ♦ Processing of catches from outside Namibia’s EEZ;
  ♦ A decline in the value of the Namibian dollar has increased the local currency unit value of exported goods; and
  ♦ Increases in value adding of landed fish through processing.

- Between 1990 and 1995 the combined fisheries and fish processing sector contributed an average of 6-7% to the GDP. During the same period these sectors contributed an
average of 22% to Namibia’s export earnings (Table 6.1). These sectors are estimated
to be responsible for 6% of total formal employment.

- Small-scale mariculture occurs in the salt pans near the Walvis Bay lagoon (mussels
  and oysters), in the vicinity of the Swakopmund salt works (oysters) and Lüderitz Bay
  (mussels, oysters and seaweed). Although shellfish growth rates in Namibia’s coastal
  waters is reported to be the highest in the world (Salt Company Pty.Ltd. pers. comm.),
  future development in this sector is limited by the occurrence of regular sulphur
  eruptions and red tides (Box 6.1) and a paucity of sheltered, accessible sites.
  Consumption of shellfish is increasing and the need to identify, monitor and predict
  harmful algal blooms in order to protect the public from potentially lethal toxicity has
  increased.

- Cast up Gracilaria verrucosa, an agarophytic seaweed, is collected for export to Japan
  in the locality of Lüderitz. 50% of this harvest is processed locally before export. The
  direct value of this industry is estimated to be approximately N$ 5 million/annum
  (CSIR, 1997).

- Namibia’s rock lobster (Jasus lalandii) industry is centred in Lüderitz, with the most
  viable fishing grounds 80-100 km north of the town. Rock lobster catches are strongly
  influenced by the oxygen level in the water – a condition that fluctuates seasonally with
  varying intensity and duration from year to year (Box 6.1). If bottom dissolved oxygen
  levels remain high during the summer, lobster have no need to migrate inshore to
  shallow waters where trapping is viable (Noli & Grobler, 1998). The most recent
  environmentally induced decline in stocks occurred between 1989 and 1992. This is
  reflected by the drop in catch from an estimated 1800 tons (in 1984) to a mere 133 tons
  (in 1992) (MFMR, 1998). TAC’s have been dramatically reduced since then and there
  has been a slow but consistent increase in catch rates. The value of the industry in
  recent years is depicted in Table 6.2.

Prolonged periods where low levels of dissolved oxygen prevail in the water are
related to climatic factors (Box 6.1) and result in decreased growth, feeding and
survival of this species (Noli and Grobler, 1998).

Table 6.2. The Value of the Rock Lobster Industry [Source: MFMR 1998]

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<tr>
<td>Value of production (N$ mily)*</td>
<td>21.0</td>
<td>28.1</td>
<td>9.9</td>
<td>10.2</td>
<td>9.4</td>
<td>15.7</td>
<td>20.2</td>
</tr>
<tr>
<td>Landed catch in tons</td>
<td>500</td>
<td>350</td>
<td>133</td>
<td>136</td>
<td>134</td>
<td>224</td>
<td>251</td>
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- There are about 16 Cape fur seal colonies of varying size along the Namibian coast
  (J.P.Roux, pers.comm) The three largest colonies are located at Wolf Bay, Atlas Bay
  (approximately 30 and 34 km south of Lüderitz ) and Cape Cross (Figure 9.1). Cape
  Cross is the only breeding colony accessible to the public attracting up to 20 000
  visitors a year. Seals are harvested mainly for their skins. The meat can be used
  as animal feed and adult male genitalia are exported to the Far East for use in
  aphrodisiacs. The number of seals harvested at Cape Cross increased by 128% between

* Value of production for Rock Lobster is equivalent to the value of exports.

Namibia’s Vulnerability to Climate Change 6. MARINE RESOURCES 65
1990 and 1993 (UCT, 1996). Total numbers harvested in Namibia in 1994 were 55,000 pups and 12,000 bulls (Swart, 1995) and, although this must represent a large amount of revenue, it is not possible to gain access to figures reflecting the economic value of this controversial resource. Anomalous environmental events can affect the seal population dramatically. During 1993/1994 exceptionally widespread anoxia of shelf bottom waters occurred in parts of the Benguela (Box 6.1) and as a result many higher predators, including 300,000 seals died from starvation (Roux, 1998). Seal population dynamics in Namibia’s waters are also directly affected by changes in the wind regime. Pups born far from the waters edge are unable to cope with the higher ambient temperatures induced by a drop in the wind chill factor — either because of a drop in wind speed or, if the hot east wind begins to blow off the desert. A few calm or hot days between mid-November and the end of December can result in daily mortalities of up to 30% of the pup population (Roux 1998).

6.4 Predicted Future Trends

- Due to expanding populations there is a growing trend in global fish consumption. However, at least 70% of the world’s commercially important marine stocks are reported to be either in a state of depletion, in the process of collapsing or slowly recovering (Oelofsen, 1998). Furthermore, many marine ecosystems display signs of irreversible damage (Box 6.2).

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Box 6.2. PERMANENT DAMAGE TO MARINE ECOSYSTEMS DUE TO UNSUSTAINABLE GLOBAL FISHING [Sources: Holmes, 1998; Oelofsen, 1998]

Despite increased environmental awareness, the world’s fishing industries are responsible for inadvertently killing between 18 and 40 million tons of fish, seabirds, turtles, marine mammals and other organisms annually — an amount that equals one third of the world’s catch. Since the early 1950s the availability of the nutritionally most valuable predatory fish species has diminished noticeably from global marine ecosystems due to overexploitation. Juvenile predators are caught in nets targeting the smaller, less valuable species lower down the food chain and irreversible damage to future fishing stocks has begun to occur. Unless protected zones are established, where no fishing at all is allowed, rebuilding healthy marine food chains is considered to be virtually impossible.

- In order to meet future demand, Rua (1998) predicts increased exploitation of low value species and the extension of fish farming industries world-wide. With the establishment of EEZ’s, new fishing powers will emerge and developing countries, Namibia included, are expected to increase their contribution to the market.

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\(^5\) This wastage of marine life is highest for industries that target one specific species. For example, the shrimp industry that functions in the Bay of Carpentaria, Australia.

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• Despite the unpredictable variability displayed by Namibia’s marine environment, there is optimism regarding future earnings from this sector. Table 6.2 depicts a summary of a projected landings for four of Namibia’s exploitable species up to 2001. In general, research focusing on both commercial stocks and the marine environment continues to improve (MFMR, 1998).

• By 2000 the fishing industry is expected to earn more than N$1.5 billion/year (in 2000 prices) (R.Blackie, pers. comm.) and provide approx. 15 000 jobs (O’Toole, 1997). Secondary activities such as netmaking, vessel maintenance, supply and maintenance of processing equipment and the production of packaging materials will also grow (MFMR 1998).

Table 6.2 Fish Landings Projections (tonnes) at current (1997/8) prices [Source: MFMR un published data]

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<tr>
<td>Pilchard</td>
<td>88 071</td>
<td>1 117</td>
<td>72 000</td>
<td>80 000</td>
<td>114 000</td>
<td>150 000</td>
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<tr>
<td>Hake</td>
<td>128 172</td>
<td>131 795</td>
<td>189 600</td>
<td>220 000</td>
<td>237 600</td>
<td>300 000</td>
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<tr>
<td>Horse Mackerel</td>
<td>310 375</td>
<td>321 322</td>
<td>378 000</td>
<td>370 000</td>
<td>426 000</td>
<td>450 000</td>
</tr>
<tr>
<td>Rock Lobster</td>
<td>285</td>
<td>251</td>
<td>600</td>
<td>800</td>
<td>720</td>
<td>1000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>557 812</td>
<td>453 540</td>
<td>723 080</td>
<td>751 800</td>
<td>885 800</td>
<td>1023 000</td>
</tr>
</tbody>
</table>

• The industry foresees an increase in exports of high value fish products to overseas markets. In addition, the opening of the Trans-Caprivi and Trans-Kalahari highways are expected to result in more efficient trade and improved export markets for marine products to landlocked country’s within the SADC region (Cummings, 1998). In order to continue fetching high prices for fish products exported to the EU and other international markets, Namibia will have to comply with increasingly stringent quality requirements.

• There is doubt as to the sustainability of harvesting some of the deep-sea species that have recently been exploited. Of particular concern is the Orange Roughy, a species that only reaches sexual maturity at an estimated 32 years of age and is thus highly susceptible to overexploitation.

• In 1995 and 1996, disagreement between the fishing industry and MFMR scientists over the accuracy of TAC’s resulted in the industry hiring its own scientists to assess the recruitment of stocks (MFMR, 1998). Opposing opinions generate uncertainty within the fisheries sector and undermine the role of government scientists. As the industry grows and becomes financially more powerful, it is expected to make increased investments into its own scientific assessment of stocks. This could result in healthy competition and, subsequently, more accurate stock assessments. On the other hand, the industry could follow worldwide patterns by exerting pressure on the government to allocate higher TAC’s than are sustainably viable.

• Present yield expectations of Namibia’s fishing stocks indicate that the proposed building of a new harbour at Mówe Bay, approximately 500km north of Walvis Bay, will not offer any primary economic benefits to the fishing sector. However, if the
optimistic values represented in Table 6.2 are reached, there is a possibility that building this new harbour could be justified (L. Clarke, pers. comm.).

6.5 Current Policy and Action

- The main goals in Namibia’s policy framework for the fisheries sector – the 1991 White paper entitled Towards Responsible Development of the Fisheries Sector - are to ensure sustainable utilisation of Namibia’s fisheries resources and to develop industries that contribute to the country’s economic and long-term development objectives. These goals are pursued through two main strategies, namely stock building and Namibianisation. Measures aimed at improving economic gain include offering incentives for:
  - onshore processing of catches; and
  - registering Namibian vessels and employing Namibian crews (MFMR, 1998).

Stock rebuilding and conservation demand both international and regional co-operation and the joint management of the Benguela ecosystem is essential for sustainable development (Box 6.3). The BENEFIT programme aims for improved regional co-operation and oceanographic research amongst the countries that share the Benguela. One of the aims of this programme is to improve understanding of the effects of the environment on fish populations and their dynamics (O’Toole, 1998).

- Namibia’s new environmental assessment policy and mining legislation make provision for environmental assessments to be conducted in an attempt to minimise the impacts of marine mining and oil and gas exploration activities. Registered offshore oil and gas exploration licence holders are expected to prepare detailed oil spill contingency plans before they embark on activities.

**Box 6.3 CONSERVATION OF STOCKS**

[Sources: Everett, 1996; Rua, 1998; MFMR, 1998]

An estimated 94% of the world’s exploitable fish resources fall under the jurisdiction of coastal countries. Although the establishment of EEZ’s encourages responsible management and sustainable utilisation of fish, many shoals migrate into the high seas, which offer a free-for-all.

The United Nation’s Convention on the Law of the Sea (1982), the Code of Conduct for Responsible Fishing (1995) and SEAFO, the regional fisheries management organisation to be established between Angola, South Africa, Namibia and other countries are amongst the important conventions that attempt to ensure that straddling stocks and shoals that migrate into the high seas, are protected from overexploitation. The extent to which these laws and agreements influence the conservation of stocks depends on proper monitoring and law enforcement. However, it is estimated that with effective management the world’s depleted fisheries could yield another 20 million tons annually. Unfortunately, only some countries are prepared to make the substantial investments required to ensure adequate surveillance and control of their fisheries sector.

Since the establishment of the Namibia’s 580 000 km² EEZ, vessels fishing illegally have virtually disappeared from domestic waters and the GRN has made concerted efforts to rebuild Namibia’s stocks. However, over exploitation is still possible and there is a strong need to implement a
6.6 Vulnerability of the marine fisheries sector to climate change

Global warming will result in many complex, interrelated atmospheric and oceanic changes (IPCC 1996). Although new generation GCM’s, like the Hadley Centre’s coupled Atmosphere-Ocean GCM (section 2.5.2.4) can be used to depict the direct effects of climate change on marine systems (sea-level rise and increases in sea surface temperature), current models are unable to provide detailed information on projected changes to ocean currents, wind regimes and upwelling processes (Glanitz, 1992; UNEP 1996) - the very factors that ultimately determine the production of Namibia’s marine fisheries sector. In addition, the lack of appropriate research on the functioning of the Benguela ecosystem limits the ability to predict the many interactive effects of global change on local marine biota. Thus, forecasting specific changes to Namibia’s physical marine environment and marine fisheries sector as a result of climate change is currently not feasible. At best, in an attempt to gain some insight into the future of the marine fisheries sector, one can piece together the following ‘what if’ scenarios based on some of the possible outcomes of global warming.

6.6.1 Potential impacts of global warming on marine systems

6.6.1.1 Ocean/atmosphere climate forcing
Sea surface temperature (SST) affects the transfer of heat energy between the sea and the atmosphere and is therefore able to influence wind speed and strength as well as the cloudiness and radiation (energy) balance of the atmosphere (NMS 1998 (b)). Global warming will cause SST to increase together with air temperatures, although not as rapidly nor to the same degree (Section 2.5.2.4). By the year 2050, these changes are likely to have a profound effect on the physical, biological and biogeochemical characteristics of the worlds oceans. This could begin to exert significant feedback responses on the earth’s climate - possibly forcing a shift of the entire global ocean-atmosphere system from one stable state to another (in Lombard 1998).

6.6.1.2 Global marine production
Although there may be significant impacts on the distribution of major fish stocks, it is hypothesized with medium confidence that under expected climate change conditions (Box 2.3), global marine fisheries production as a whole is likely to remain unchanged. If current stresses on fish stocks, particularly overfishing, are curtailed, global production could even become significantly higher (Everett 1996).
6.6.1.3 Productivity of the Benguela

- Increased SST and higher levels of atmospheric/oceanic CO₂ are likely to enhance the photosynthetic rate of phytoplankton and other marine plants. However, this improved primary production could be either offset or further enhanced by the reduced/increased availability of nutrients in the surface waters. This, in turn, will depend on changes to the wind regime and the upwelling process.
- Wind and pressure regimes around the world will be affected by the weakening of the temperature gradient between the equator and the poles. Altered trade winds will lead to changes in the intensity, duration and frequency of coastal upwelling and ultimately the production of the Benguela System. Constant strong winds would reduce net primary production because phytoplankton become light-limited by deep mixing in the water column. However, a moderate increase in upwelling winds and enhanced thermal stability of the water column could enhance primary production dramatically (Brown and Cochrane 1991).
- Even without major change in atmospheric and oceanic circulation, local shifts in centres of production and mixes of species are expected as ecosystems are displaced geographically (Everett 1996). Increased water temperatures will lead to changes in the metabolic rates of fish, their migration times and routes and rates of development and spawning periods - ultimately influencing their distribution and population dynamics. Small changes in temperature, circulation patterns and nutrient availability are likely to significantly alter the oceanic areas where fish larva could survive (Bakun 1990).

6.6.1.4 Possible implications for Namibia’s marine fisheries sector

A summary of the potential effects of climate change on Namibia’s marine fisheries sector is presented in Table 6.3. In the short to medium term it is likely that climate change will not create new problems for marine fisheries as much as it exacerbates existing ones. Siegfried et al (1990) suggest that global warming will drive an increase in the frequency of warm water events or Benguela Niños (Box 6.1). Furthermore, if the upwelling regime remains unchanged, increased SST will give rise to more frequent sulphur eruptions and anoxic water events (Box 6.1). These responses will impact on the size and production of Namibia’s various fisheries.

Growth in the fish processing sector comes from both increases in the number of fish caught and processed (dependent on production level of the system) and increases in the value added per fish. (Blackie 1998). Predicted growth for this sector is roughly estimated to be somewhere between 8-17% for the period 1998-2007 and 8 – 14 % for the period 2008-2017 (Table 3.2). It is not possible to ascertain with any degree of accuracy the magnitude and timing of the expected climate change impacts. At best one can assume that, as a result of a potential increase in the occurrence of environmental anomalies, Namibia’s future fisheries sector is likely to be subjected to altered fish production. However, not all species will suffer and less valuable catches, e.g. Horse Mackerel, may benefit from these conditions.
After about 2050 permanent changes to the Benguela upwelling could result. Many species may disappear from Namibian waters entirely, to be replaced by more diverse assemblages adapted to warmer conditions. Increased intrusion of warm tropical waters from Angola may cause the pelagic ecosystem off the Namibian coast to permanently revert to its temporary state of the early 1960’s - when sardines, anchovies and gobies were abundant (Siegfried et. al 1990). Although increased biodiversity is likely to occur under these circumstances, the production of the Benguela will ultimately diminish. This would herald severe repercussions for the marine fisheries sector.

Table 6.3 **Potential effects of climate change on Namibia’s marine fisheries sector**

<table>
<thead>
<tr>
<th>Climate Induced Changes</th>
<th>Some Primary Effects</th>
<th>Potential Ultimate Effects</th>
<th>Most Vulnerable Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increased occurrence of: warm water events (Benguela Niños), sulphur eruptions; lowered oxygen levels; red tides. Disappearance of some cold water species. Warm water species infringing from the south-east and north. Disruption of upwelling zones and distribution of nutrients. Altered primary production (affected by both temperature and nutrient availability).</td>
<td>Changes in species composition of the Benguela. Increased variability of fish stocks and episodic mass mortalities. The need to establish new TAC’s / fishing quotas and/or geographical restrictions.</td>
<td>Long lived species and species that have been heavily or over-exploited eg. lobster, hake, orange roughy. Species dependent on inshore wetland nursery areas that may be vulnerable to sea-level rise and other impacts. Cold-adapted species with narrow T° ranges and limited adaptation to altered levels of O(_2).</td>
</tr>
</tbody>
</table>

6 The west coast steenbras, *Lithognathus mormyrus*, one of Namibia’s important line angling species, is believed to be highly dependent on inshore wetland nursery areas for breeding. Natural geomorphological changes at Sandwich harbour and man-induced changes to the Walvis Bay lagoon (Section 9.5) are believed to be responsible for the recent dramatic decline in numbers of this species (H. Holtzhausen pers. comm.).

6.7 **Conclusions**

Any climate change impacts on the world’s marine resources will be superimposed over existing stresses to the marine environment, including the overexploitation of resources and increasing pollution. Thus, convincing industry at a local, regional and global level, to sacrifice current short-term gains in place of the long-term benefits that will result from the sustainable management of marine resources, is essential to help reduce vulnerability to the potential effects of global warming.

The development of EEZs during the 1990s was essential to lay a foundation for improved management of national marine stocks. Nevertheless, these invisible boundaries could
prevent many countries from adjusting to the geographical shifts in fish distribution that may accompany global warming. Although it is not possible to ascertain with any degree of certainty the exact nature of the many interrelated effects of climate change on marine systems, it is probable that impacts on global marine fisheries will be accompanied by new economic winners and losers.

Some Recommendations

- Create coastal and marine reserves and ensure that the local management of fisheries is integrated with other uses of coastal zones.
- Conduct assessments of the consequences of current human pressures on regional resources, including the effects of species overexploitation and coastal pollution.
- Develop and improve existing models for forecasting marine environmental changes associated with the eastern tropical Atlantic and the Benguela current ecosystem.
- Conduct an in-depth assessment of the current status of each fishery and how it responds under present variable climatic conditions i.e. to red tides, sulphur eruptions and during Benguela Niño years. This will provide insight into how Namibia’s marine fisheries, and the industries dependent on them, are likely to cope in the face of an extremely uncertain climatic future.
- Monitor consumer health problems that could increase under climate change conditions, e.g. those associated with red tides.
- Implement policies that encourage fish processing over larger catches. A reduction of fishing pressure on fully and overexploited species will help to increase their resilience to the direct effects of climate change. Support all efforts (e.g. the BCLME and BENEFIT projects) to develop integrated regional strategies to protect the marine environment and manage the resources of the Benguela Current ecosystem on a sustainable basis. Encourage species conservation that is balanced against future economic needs and expectations regarding the availability of stocks.
- Implement national and international policies that recognise that species ranges are likely to shift and that each exploitable species is likely to become more/less accessible and more/less abundant in the future.
AGRICULTURE
7.1 Land use in Namibia

Namibia’s political history, ecology and climate have determined past and present land use patterns. Nomadic pastoralism, dictated by the availability of fodder and water, was practised extensively during the pre-colonial period. In the higher rainfall regions, communities were more settled but confined to areas of reliable water. German colonial policies and subsequently the South African apartheid administration laid the foundation for the way in which Namibia’s land is currently divided and utilised (Figure 7.1). As a result:

- Close to 70% of Namibia’s population practice subsistence crop farming and agro-pastoralism on communal land. This land belongs to the State and constitutes approximately 41% of the total land area of the country.
- Commercial farmers (less than 1% of the population) own approximately 44% of the land.
- 2% of the total land area is comprised of diamond mining areas.
- 13% has been proclaimed as conservation areas.

7.2 Overview of agriculture

- The colonial era created two agricultural sub-sectors, communal and commercial, which jointly contribute an average of approximately 10% to the GDP (Appendix 2).
- Approximately 48% of the actual Namibian labour force is employed by the agricultural sector, with an estimated 70% of the population dependent either directly or indirectly on agriculture for its livelihood (MoL 1997).
- Namibian soils are generally poor. Stock carrying capacity is very low, varying between 8 ha/large stock unit in the northeast to 24 ha/large stock unit in the south (Hutchinson 1995).
- Although cattle numbers on commercial farms have declined to 45% of the 1960 levels (Lange et al 1997), significant increases in small and large livestock numbers have occurred in Namibia’s northern communal areas (Marsh and Seely 1992; Mendelsohn and Roberts 1997)
- The main environmental constraints that limit the development of agriculture are periodic drought, desertification, and low levels of soil moisture during most of the year (even in the absence of drought). Lack of precipitation restricts arable farming to the north of the 19° latitude (Hutchinson 1995).
- Despite the climatic and topographical constraints, 85% of the country is used for agricultural purpose. More than 90% of this land is used for livestock farming and less than 10% for crop production (Köhler 1997).
- Drought impacts heavily on Namibia’s agricultural sector and rural food security (Box 7.1). Between 1990 and 1997 livestock losses were predominantly due to the effects of drought (Appendix 11).
FIGURE 7.1 Land tenure in Namibia

Land Tenure

- State Protected Nature Area
- Open Communal Area
- Sub-divided and Surveyed Communal Farmland
- Tourist Recreational Area
- Restricted Area for Mining
- Commercial Farmland
- Major Towns
- Small State Protected Areas

Source:
Various Government Gazette published by the Government of Namibia.
Ministry of Lands, Resettlement and Rehabilitation Division of Survey and Mapping 1:250000 maps.
National Remote Sensing Centre 1997

Namibia's Vulnerability to Climate Change. 7. AGRICULTURE
7.2.1 Communal farming

- In the south and west-central communal areas, smallstock predominate. In the north mixed subsistence farming is practised but livestock farming is the major agricultural activity. Variable rainfall, poor soils and distant markets limit the development of farming in the communal areas. As a result, agricultural incomes are low and variable (Box 7.1).

- Currently, approximately 274,000 hectares are used for rainfed crop production (mainly millet, which is well adapted to low rainfall conditions) by 137,000 rural households (MoL 1997).

- Communal agriculture makes a modest contribution to Namibia’s GDP but is vital for most rural households. Livestock in the communal-tenure sector supply many non-marketed products and services, the value of which is not fully reflected in the national accounts. These include draught power, milk, hides, manure and a form of savings for communities not served by banking facilities (Lange et al 1997).

- Possibilities for appropriate animal husbandry practices in communal areas are reduced as the number of absentee farmers investing in livestock grows. In recent years traditional authorities have begun to lose their influence over communities and illegal fencing of land has become common (Fitter et al 1996).

- In the 1960’s veterinary fences were erected to prevent the transmission of contagious stock diseases (bovine lung-sickness and foot-and-mouth disease) from communal cattle in the north to stock raised on commercial farms. These fences have limited the export marketing opportunities of communal farmers but have been essential for the maintenance of livestock exports from herds south of the fence, the majority of which are from private tenure farms.

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**Box 7.1. RURAL HOUSEHOLD INCOME, FOOD SECURITY AND DROUGHT**

[Sources: Ashley and La Franchi 1997; MoL 1997; M.Fowler pers. comm.]

Although 94% of rural households identify agriculture as their main activity it currently makes a small and declining contribution to communal farmers’ household income. Less than 20% of household income is estimated to come from agriculture in the Omusati, Oshana, Ohangwena and Oshikoto regions, 16% in Kavango and 34% in Caprivi. High variability in harvests between years is evident and most households in most years, are unable to produce enough grain for the families’ requirements. Basic nutritional needs, especially during years of drought, are met through gathering *veldkos* (edible wild plants), hunting/trapping fish and other wildlife and through barter and exchange. Wages earned in towns and/or pensions are also used by some families to purchase food. Although the majority of wild products are not marketed, some (fish, game, home-made drinks and baskets) are traded for cash.

Extended periods of drought impact heavily on the tenuous food security of Namibia’s rural poor (Section 7.4.3). During times of drought, crops become increasingly vulnerable to damage by insects, birds, nematodes, rodents, bacteria and fungi. As ground water levels drop and surface water dries up, the spread of communicable diseases is facilitated, thus further limiting the ability of people to cope.
7.2.2 Commercial farming

- Commercial farms (mainly livestock) are large (averaging 6 000 – 12 000 hectares) and oriented towards production for the market (Lange et al. 1997). In the south small stock farming is practised and in the north/central region cattle are ranched.
- Rainfed and irrigated commercial crop production occurs on 25 000 hectares in the Karst area (Tsumeb, Otavi, Grootfontein ‘maize triangle’), on small plots at the Hardap scheme, near Stampriet, and along some of the perennial and ephemeral river courses (MAWRD 1995).
- Livestock and related industries (meat and meat products) accounted for an average of 8.2% of GDP between 1988 and 1996 (Appendix 2) and nearly 16% of visible exports in 1995. Meat and meat products, live cattle and other stock (mainly for the South African market) make up 90% of all agricultural exports (MAWRD, 1995). Since the 1970’s many commercial livestock farmers have moved towards mixed game/livestock farming. This diversification helps to protect biodiversity and is likely to create a valuable buffer against drought (Section 8.4.1).

7.2.3 Causes and effects of land degradation in Namibia

Desertification is defined as land degradation in arid, semi-arid and dry, sub-humid areas, resulting mainly from negative human impacts combined with difficult climatic and environmental conditions.

Desertification occurs when there is a decrease in plant cover or when one type of vegetation is replaced with other, often less productive species. It reduces the production potential of agricultural land (sometimes permanently), limits opportunities for other forms of land-use and is considered a major cause of biodiversity loss in Namibia. The degree of desertification hazard for most of Namibia is considered very high (Booth et al. 1996).

The reduction of perennial plant cover that sometimes accompanies the desertification process is usually attributed to overgrazing (Box 7.7), the clearing of land for crop farming and poor cultivation techniques. Nevertheless, poor land management alone does not account for undesirable shifts in vegetation. Although, unsuitable agricultural practices have certainly exacerbated the situation, there is evidence to suggest that the shifts from grassland to semi-arid Karoo scrub vegetation which have occurred in the eastern Cape Province of South Africa over the past 300 years have resulted largely from natural climatic changes (Bousman and Scott 1994).

Thus, the indirect causes of desertification in Namibia result from several interlinked climatic, social and political factors (Figure 4.1 and Box 7.2) the effects of which render much of the land susceptible to drought. The main environmental manifestations of desertification in Namibia - soil erosion, bush encroachment and soil salination - directly threaten the livelihoods of rural communities and intensify rural poverty. Shifts in the balance of perennial to annual plant grasses and palatable to non-palatable species are often signs that degradation has occurred.
INAPPROPRIATE POLICIES AND DEVELOPMENT
Past policies and actions discouraged farmers from adopting management practices suited to Namibia’s natural aridity and have directly contributed to desertification in Namibia. These included drought relief subsidies to farmers for livestock, crops and water and an increase in the provision of permanent water points in marginal areas through ongoing rural water supply development, resettlement schemes and drought relief programmes. Deteriorating land degradation has also resulted from a lack of secure land tenure and inappropriate irrigation policies.

POPULATION PRESSURE AND POVERTY
These are major causes of land degradation, especially in the communal farming areas where heavy demands are made on natural resources and there are limited opportunities for off-farm employment. Desertification, in turn, causes poverty in Namibia’s most densely populated rural areas where the livelihood strategies of many people are threatened by diminishing resources.

FIRE
Fire is commonly used as a tool to clear land for cultivation, stimulate grass growth for grazing and to improve soil fertility. However, if employed too late or early in the dry season, fire leaves the soil baked hard and bare increasing its vulnerability to wind and water erosion. Growing human populations are the cause of more frequent fires throughout subtropical Africa. Areas in the Caprivi region which are burnt repeatedly have proved to be particularly vulnerable to land degradation.

FENCING
Fenced off lands often suffer degradation. In communal farmlands, the illegal fencing of prime grazing areas by rich farmers is becoming common practice. This results in many smaller scale farmers being forced into marginal areas which are being selectively overgrazed.

CLIMATE
Drought is a normal feature of arid and semi-arid areas and in the absence of human and livestock interference, does not usually cause any form of degradation. However, heavy rains falling after a lengthy dry period on overgrazed rangelands can result in severe erosion. In these areas a situation whereby “Drought increases soil degradation and soil degradation magnifies the effects of drought” can easily be triggered. A number of areas in Namibia are becoming increasingly vulnerable to degradation due to drought as a result of heavy grazing pressure during dry periods.

DEFORESTATION
Wood is the primary energy source for an estimated 60% of the population in Namibia. 96% of all Caprivian households use wood for fuel and 88% of all dwellings in Caprivi are constructed from wood. This extensive use is not sustainable and the area is likely to suffer severe degradation in the future. Deforestation in some areas, including the Onwuti, Oshana, Ohangwena and Oshikoto regions in northern Namibia, has been so thorough that families now resort to using cattle dung as fuel, thus denying the soil vulnerable nutrients. Expanding cultivation, in order to provide food for growing populations, is also responsible for deforestation. Little effort is made to restore soil nutrients and new areas are cleared when existing lands are no longer considered to be fertile. In 1996, a total of 1719 km² were cleared in Caprivi - an activity that has increased at a rate of 4.1% each year since 1943.

Besides removing valuable CO₂ sinks from the environment, deforestation is capable of causing soil erosion, disrupting essential environmental processes (Figure 7.2) and facilitating the spread of certain vector-borne diseases (Section 10.3.2.2).
Desertification is capable of impacting significantly, not only on the Earth’s surface, but also on the atmosphere. Rates of evapotranspiration, ground and air temperatures, near surface wind speeds and turbulence levels, and rates of precipitation are all affected by degraded land. These climatic responses are felt locally but may become regional in scale depending on the extent of desertification (Williams and Balling, 1996).

7.2.3.1 Soil Erosion
Soils in arid and semi-arid areas, typical of those found in Namibia, are inherently vulnerable to desertification processes since they have low levels of biological activity, organic matter and aggregate stability (Le Houérou 1996). Over most of Namibia, the initial rains of the season (usually beginning in November) have the highest intensity and propensity to cause soil erosion. Wind erosion is most likely during the dry season (July to October/November) when stronger winds prevail in the interior (Strohbach et al, 1996).

Namibian rangelands are particularly vulnerable to overgrazing. Soil erosion is unlikely to occur when the soil is covered by a dense stand of perennial grass. However, erosion is rapid when perennial grasses are overgrazed, particularly during times of drought (Box 7.7). Sedentarism, which has replaced the transhumance of the past, has resulted in excessive numbers of livestock grazing for too long in the same place and is responsible
Figure 7.3. Estimated Vegetative Cover (October 1994)\textsuperscript{2}

[Source: Strohbach, \textit{et al.}, 1996]

\textsuperscript{2} Caution must be taken in the interpretation of this map. Some differences in plant cover depicted on the map can be attributed to the differences in soil type and geology (e.g. as seen at the border between the central and southern Namib which are separated by the Kuiseb River). Cloud cover obscured the measurements in some areas (e.g. the Caprivi) which can be expected to have a higher plant cover than depicted (Strohbach, \textit{et al} 1996).
for the depletion of arid adapted perennial grasses and most of the soil erosion in Namibia (Ashley 1994).

It is important to quantify the rate at which land degradation is increasing in Namibia so that estimates regarding the loss of carrying capacity and agricultural production can be made. Only once this has been done, can economically and ecologically viable options for livestock production, mixed wildlife/livestock ranching or other land-use activities be properly assessed and planned for. The results of such investigations will also have important implications for land reform, and drought and agricultural trade policy (Lange et al. 1997).

Although soil scientists are not yet able to determine the rate at which soil erosion is occurring, an Erosion Hazard Mapping Project – aimed at assessing the potential for soil erosion in Namibia, is in process. This project, which was initiated by SADC/ELMS, is employing the Soil Loss Estimation Model For Southern Africa (SLEMSA). The higher the percentage of plant cover, the lower the chances of soil erosion. Thus, part of this model involves developing a vegetation crown cover ‘worst case scenario’ for the country. Figure 7.3 depicts the estimated vegetative crown cover over Namibia for October (the end of the dry season when plant cover is at its lowest) in 1994. Although this map does not necessarily represent a worst scenario for the country, it gives a fair representation of the low plant cover during a typical pre-rainy season and offers some indication of the country’s susceptibility to erosion (B. Strohbach, pers. comm).

7.2.3.2 Bush encroachment

Bush encroachment is believed to result from overgrazing, poor range and livestock management, and the absence of browsers (Lange et al. 1997). It causes the replacement of palatable perennial grass species by dense thickets of bush (mainly Dichrostachys cinerea and Acacia mellifera) which are unpalatable to cattle and sheep.

- Severe bush encroachment which occurs mainly on commercial farmland is reported to cover between 12 - 14% of the country, affecting 8-10 million hectares of land and reducing the production of some cattle ranches by up to 30% (Bester 1996).
- Mendelsohn and Roberts (1997) report that in certain areas of the Caprivi, fire-induced bush encroachment has begun to occur, with bushy thickets invading previously open woodland.
- Bush encroachment is not always viewed as a problem and in some parts of southern Africa, rural inhabitants value the wood as good sources of fuel, grazing (for goats) and fencing material (Booth et al. 1996). Certainly, the thorny thickets that result help to prevent soil erosion, provide sinks for greenhouse gases, and can encourage an increase in certain wildlife species, particularly in areas previously set aside for cattle. Wood from D. cinerea and A. mellifera is suitable for conversion into charcoal. Depending on whether markets can be found, charcoal production could provide a financially viable means of bush encroachment control in the future. Replacing cattle with wildlife browsers is also a potential option to help control bush encroachment.

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2 This model also requires the development of an average slope map, the development of a detailed soil map to help determine soil erodability and measurements of the propensity of rainfall in Namibia to cause erosion (M. Coetzee pers. comm.).
7.2.3.3 Soil salination
Some Namibian soils are susceptible to salination. This phenomenon occurs when precipitation is exceeded by evapotranspiration. It results in a concentration of salts near to the soil surface rendering it difficult for the plant roots to absorb water. Irrigated soils, particularly in the Stampriet and Hardap areas and the Swakop River valley are highly vulnerable to the effects of salination (Köhler, 1997).

7.2.3.4 Estimated socio-economic implications of desertification in Namibia
- The trees and shrubs that cover 80% of Namibia play an essential role in maintaining environmental stability and supporting rural human populations (Figure 7.2). Their possible replacement by an unsustainable farming system in Namibia’s more heavily populated rural areas could severely threaten the environment and the livelihoods of future generations.
- In 1994 desertification was estimated to cost rural communities approximately N$ 80 million per year (current not constant prices) due to lost access to grazing, fuelwood and timber, reduced output of milk, meat and manure, lower crop yields and increased expenditure on substitutes (Quan et al 1994).
- In 1994 bush encroachment was estimated to be costing the commercial sector N$ 102 million/annum in lost grazing. Loss in export earnings from beef over the last 30 years is estimated to be up to N$ 500 million and losses in income tax revenues due to declining livestock productivity are estimated to be in the region of N$ 12.7 million/annum (ibid).

7.3 Future socio-economic trends and challenges independent of climate change

In order to develop some idea of how climate change will affect agriculture and food security in the future, it is necessary to consider possible socio-economic scenarios based on future expectations for this sector - particularly the growing demands of an expanding population on food supply. Current policies and programmes will help determine the path down which the agricultural sector will move in the future and some of these have also been reviewed in this section.

7.3.1 Future scenarios
The following represents a worst-case scenario for the agricultural sector in forthcoming decades:-
- Namibia’s expanding population will cause an increased demand for arable land in the future. In the Caprivi region it is estimated that at the present rate of clearing, all areas with the best soils for cultivation will be cleared by the year 2033 and all land (including that with the poorest soils) will be cleared by the year 2082 (Mendelsohn and Roberts 1997).
- The need for off-farm income generating activities will intensify, as the agricultural sector becomes increasingly less able to provide sufficient remunerative livelihoods for the country’s growing population. The slow growth of non-agricultural employment in Namibia means that the majority of the population’s direct
dependence on wood for fuel, cattle as a store of wealth and income and crops and veldkos for food, are likely to continue for generations to come (Ashley et al. 1995).

- Declining food production that results from land degradation will result in a greater dependence on food imports for urban populations and increase the vulnerability of poor rural households to drought (Box 7.1). The economy will need to generate enough foreign exchange from mining, fisheries, tourism and other sectors in order to secure the food imports upon which the food security of Namibia will become increasingly dependent.

- It has been suggested that in 30–50 years time, if current rates of soil degradation are maintained, crop yields in the southern African region could be reduced by 50% (Booth et al. 1994). This will threaten South African and Zimbabwean cereal exports and impact heavily on food security in Namibia and other countries in the region.

- In addition to future environmental constraints, Namibia’s farmers are likely to be subjected to changing economic conditions that will negatively effect the agricultural sector (Lange et al. 1997). It is estimated that the implementation of the WTO agreement, which involves the eventual end of Namibia’s preferential access to European Union markets and the liberalisation of trade between South Africa and the European Union, will threaten Namibia’s export market in South Africa and Europe and could cause prices for Namibian livestock products to drop by up to 20% (Low, 1994).

- Although the southern African region is currently enjoying relative peace and stability, it is important to acknowledge that future armed conflict is not impossible. Many civil wars have indirectly resulted from the inability of governments to cope effectively with the consequences of environmental degradation and drought. Wars place pressure on resources and large refugee settlements are usually associated with an increase in deforestation and soil degradation (Booth et al. 1996; Dalal-Clayton 1996).

This scenario does not consider the following uncertainties regarding future population and economic growth. If taken into account, a more optimistic scenario can be created.

- Figures for land clearing do not account for the possibility of increased intensification of production e.g. through improved soil fertility, more efficient use of water, improved cultivars and crop management practices.

- Future population projections for Namibia and the SADC region as a whole are not certain. Recent estimates suggest that Namibia’s population growth rate could drop from the current 3.2% per annum to as low as 0.1% per annum by 2016, due to the HIV/AIDS epidemic (Section 3.3.1).

- If Namibia’s future economic expectations are realised (Section 3.3.2) pressure on the land and other natural resources may be reduced as employment opportunities in trade, industry and tourism are improved. The development of conservancies (Section 8.4.1), which encourage people to become involved in tourism enterprises and to monitor resources within their communities, hold great promise for improved land management and rural socio-economic upliftment in the future (Section 8.4.2).

- If Namibia shifts the use of water away from irrigated agricultural produce that is not cost effective, this ‘freed’ or virtual water could be used to develop industries within
the country that specialise in the production of goods that have a cost advantage (Table 5.3). It is estimated that if Namibia imports all her cereal requirements by 2030, then the total quantity of saved (or virtual) water would be 1.5 billion m³ /annum (DRFN, 1998). Thus, increased food imports could indirectly be highly beneficial to Namibia’s future economy (Box 7.3).

Whatever future scenario does result, agricultural growth rates are not expected to rise much above 5% per annum over the next 20 years (Table 3.2).

Box 7.3. FEEDING NAMIBIA’S GROWING POPULATION
[Sources: - MAWRD, 1995; Dewardcy, 1996; Köhler, 1997; B. Groom & R. Blackie pers. comm]

Although Namibian producers currently supply all of the nation's red meat requirements, the country has not been self-sufficient in grain production since 1964. Crop output fluctuates considerably in response to the country’s highly variable rainfall and in good rain years (roughly 4 years in ten) Namibia manages to produce only half of her grain consumption needs – a proportion that will continue to diminish as the country’s population grows. Food imports include maize, wheat, sugar and dairy products - over 85% of which are imported from South Africa. To produce enough cereals locally to sustain Namibia’s current population could require more than Namibia’s total available internal water resources.

Although new irrigation projects that aim for self-sufficiency in food production will create jobs and offer opportunities for rural development, they will require enormous subsidies and are capable of accelerating land degradation through pollution, soil salination and their high water demands. There is no advantage to growing crops in Namibia that have high opportunity costs, are not arid adapted and are unable to carry the full price of their water need and it is estimated that between 1991 and 1997 the average quantity of saved water (or virtual water) that resulted from importing maize and wheat from countries better suited to their production, was 309 Mm³ /annum (more the volume of water Namibia used in 1993).

As a first step towards future food security, water subsidies, particularly for low value crops such as wheat and maize that are not economically viable to grow in Namibia at full cost recovery water prices, should be discontinued. In the past price support from the Namibian Agronomic Board for commercial maize and wheat producers distorted the relative economic returns from these products at the expense of the environment. Replacing low-value cereal crops with higher value fruit and vegetables (for example, citrus fruits and grapes) that are more water-efficient is now being considered.

7.3.2 Current Policy and Action

This section offers an overview of policies and projects relating to land degradation, land tenure and food security, thus providing some insight into the future of Namibia’s agricultural sector.

- The GRN is a signatory of the United Nations Desertification Convention. Land and natural resource management, water, agriculture, forestry, poverty, population and economic policies are all related, either directly or indirectly, to desertification in Namibia. Since independence, a number of policy statements have emerged in these
fields but implementation is often extremely slow and policy contradiction and failure
is all too common (Vigne and Whiteside, 1997; Tarr, in prep). Subsidies paid out to
farmers as part of poverty reduction and drought relief strategies have created
unrealistic expectations and hinder efforts to combat desertification. Other attempts to
alleviate poverty, for example the MLRR’s resettlement programme, have been
criticised for their lack of forward planning and their ability to accelerate land
degradation (Box 7.4).

Nevertheless, local initiatives like NAPCOD and SARDEP, that represent
partnerships between government, NGO’s and communities aim to promote drought
preparedness and improve flexibility to a changing environment. In addition, the
recently promulgated National Drought Policy and Strategy (1998) aims to ensure
that the short-term inefficient drought relief efforts of the past are replaced by long-
term sustainable drought management (Appendix 12). If this policy is successfully
implemented it will go a long way towards helping to slow down the rate of land
degradation in Namibia, reduce poverty and improve rural food security.

- The rate of deforestation is cause for concern and providing energy to present and
future generations without causing irreversible environmental damage has become a
major challenge (Section 11.3). Although the Ministry of Mines and Energy are
beginning to investigate the possibilities for wind and solar-powered plants, much
more attention needs to be given to the potential of renewable energy sources (section
11.5).

- Namibia’s Meteorological Services (NMS) is in the process of establishing
normalised difference vegetation images from NOAA satellites to help monitor
forage conditions over Namibia. Such a system will be prove invaluable to the
Agricultural Sector of Namibia and could be used to:
  - Supply information to Namibia’s Early Warning & Food information System
    and the National Drought Force;
  - Create a new carrying capacity map for Namibia;
  - Help advise farmers on their response to adverse weather conditions; and
  - Help determine grazing areas and distribution of livestock in the communal
    areas.

- Since independence, the GRN has redirected development efforts towards farmers in
the previously neglected communal areas. This has led to an increase in the number
of cattle slaughtered and marketed north of the veterinary cordon fence. The
conservation of indigenous (Sanga) livestock, which display high tolerance to dry
environments and have developed a natural resistance to tick-borne and other
endemic diseases, has become a high priority in the MAWRD’s National Research
Policy (Barnard 1998). Furthermore a number of NGO and government sponsored
programmes have been developed in support of the policy to focus efforts on
improving animal health in the communal-tenure areas. Included amongst these
programmes are those focussed on implementing sustainable rangeland management
practices (e.g. SARDEP and NOLIDEP).

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Many of the resettlement schemes aimed at providing historically disadvantaged, landless people adequate access to land are criticised for being unsustainable (Box 7.4) and Cabinet continues to approve contradictory sector policies and legislation. In spite of this, the implementation of Namibia’s EA policy, various SADC-level joint management programmes, and local initiatives such as CBNRM do offer some opportunities for encouraging intersectoral planning and developing non-agricultural employment opportunities (Section 8.5).

**Box 7.4. RESETTLEMENT, POVERTY ALLEVIATION AND LAND DEGRADATION.**
[Sources: Fitter, et.al. 1996; NAPCOD,1997; NAPCOD,1998]

NDP 1 has an objective to provide adequate access to land for historically-disadvantaged people. In response, the MLRR has resettled 16 000 - 17 000 landless Namibians since independence. Of concern is the noticeable lack of information on the environmental costs and benefits of the resettlement process.

The successful implementation of resettlement is constrained by Namibia’s biophysical characteristics (poor soil, low and variable rainfall and high temperatures), which strongly limit the potential for sustainable agricultural practices. Many of the schemes are focused on resettling communities and their cattle on land unsuitable for permanent settlement (for example, the Gam area in the eastern Otjozondjupa region) or developing dryland cropping for communal farmers in areas where livestock production previously took place on marginal or already degraded land.

Private tenure versus a system of open management is currently being debated. Although there is a strong argument that private tenure will encourage sustainable management because of ownership, an alternative view is that resettlement schemes should practice common property tenure systems. This will allow greater flexibility, more efficient use of resources (e.g. grazing) and lowered risk of overgrazing in arid and semi-arid areas subjected to extreme climatic variability (Box 7.7).

### 7.4 Climate Change and Agriculture

The most certain aspects of climate change are increased temperatures and higher CO₂ concentrations. These impacts alone could have a profound effect on future crop yields and the primary productivity of rangeland grasses (Box 7.5). Changes to soil parameters such as soil water retention constants are also likely (Schulze et al 1993) and alterations in the prevalence and spread of weeds, pests and livestock diseases are highly probable.

However, fundamental gaps remain in our knowledge of future environments – in particular there is large uncertainty surrounding the quantification of future rainfall variability. Furthermore, it is not easy to ascertain plant responses to the combined effects of increased concentrations of CO₂ and elevated temperatures (Box 7.5). It is also not feasible to determine exact changes in technological and cultivation practices which could affect future crop-climate relationships nor to know how altered social, economic and political conditions will affect future agricultural output (Section 7.3). Nevertheless,
If temperatures rise, plants in warmer climates will experience lower soil water availability and primary production should decrease. However, under higher concentrations of CO₂ the water-use efficiency (WUE)⁵ of a plant increases. This, together with other effects of CO₂ enrichment (diagram above), is likely to bring into effect several positive feedback responses. In light of the following caveats, these exact responses are difficult to quantify:-

- For plants of the C3 type (most tree species and crops, such as wheat, rice and soya beans) rates of photosynthesis may increase in the presence of doubled concentrations of CO₂. C4 type plants (many subtropical and semi-arid pasture grasses as well as crops such as maize and sugar cane) are generally more efficient at fixing CO₂ than C3 type plants and could display less of an improvement in the presence of increased CO₂.

- Non-optimal nutrient conditions are likely to limit the CO₂ enrichment effect in natural ecosystems as a lack of nitrogen and phosphorus⁶ in the soil are known to hinder carbon uptake.

- Reductions in forage quality and palatability could occur because of increasing carbon to nitrogen ratios, particularly on rangelands where low nutritional value is already a problem.

- Increasing temperature in some biomes will result in increased nitrogen mineralisation which would enhance CO₂ uptake.

- Some plants may adapt to higher levels of CO₂ and cease to react to its effect after a while.

Thus, the actual response of a plant species to increased CO₂ will ultimately depend on its location, function and competitive ability within an ecosystem as well as any temperature and nutrient changes it is subjected to as a result of global change.⁷

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⁵ WUE is defined as the ratio between carbon gain (photosynthesis) and water loss (transpiration). In addition to leading to increased productivity under similar moisture conditions, enhanced WUE allows plants to invade more arid environments (Hulme et al 1996)

⁶ Namibian soils are particularly deficient in phosphates (B. Strohbach, pers comm.)

⁷ The interactive effects of changes in land-use, atmospheric composition, biological diversity and climate change are collectively termed global change (Section 8.6). Therefore, the effects of increased UVR (particularly UV-B radiation) on the growth rates and disease susceptibility of plants should be included here. Increased UVR is a direct response to
Climate change and agriculture cont.
assessments within the region which have focussed on projected changes in potential yields of maize as well as broad-brush investigations into some climate change effects on rangelands, currently offer some general indications regarding future possible shifts in agricultural productivity and lay a foundation for future research in this field.

7.4.1 Maize farming - local and regional responses to some aspects of climate change

- The regional study conducted by Hulme et al (1996) indicates that the growing season of maize (the staple grain of southern Africa) is likely to shift to an earlier date over much of the region. As a result of increased temperatures, shorter growing seasons are likely - a situation that could reduce yield quality (i.e. the ratio of nitrogen/protein to fibre in the grain).

- Based on the influence of increased CO₂ and temperature alone, climate change is unlikely to cause a widespread loss of agricultural suitability in southern Africa. With appropriate flexibility regarding cultivars and planting time, maize production in the region could be as viable as if there was no climate change. However, there are likely to be definite geographical differences in where crop yields increase and decrease (ibid).

- Increased water use efficiency due to enhanced CO₂ (Box 7.5), is estimated to largely overcome the effects of increased temperature in most of the semi-arid regions of SADC (ibid.) Based on Hulme’s assessment of the maize water balance for 1961-90, Namibia’s maize triangle and Caprivi strip fall into the fair to good maize yield category (an estimated maximum water requirements satisfaction index [WRSI] of 85-95). Changes in this index under the ‘core’ climate change scenario (Section 2.5.2.3) indicate a possible 0-5% increase in maize yield in these areas.

Nevertheless, rainfall variability and prevalence of drought remain the major determinants of future agricultural productivity and yield reliability within SADC. Under a general aridification scenario there will be fewer areas suitable for cultivation and increased rainfall variability, as suggested by Hulme’s ‘core’ scenario, will undoubtedly threaten future food security in the region. Surface water availability is also likely to decline under the ‘core’ scenario and this will be accompanied by fewer opportunities to compensate for lost productivity through irrigation schemes.

7.4.2 The sensitivity of Namibia’s rangelands to climate change

There is very little true grassland in Namibia. Most of the country’s non-desert vegetation is savanna – comprised of grass, trees and shrubs. Namibian savannas support large cattle, sheep and goat herds and provide a range of habitats for wild species. Typical of southern African ecosystems, these rangelands respond to many interlinked factors including the effects of fire, precipitation, nutrient availability, atmospheric composition, loss of biodiversity and different types of grazing pressure (Figure 8.4 and Section 8.6.1).

the depletion of ozone in our atmosphere and is not usually included in discussions pertaining to the effects of global warming.
Many feedback mechanisms occur between some of these factors and each one will be affected, either directly or indirectly, by an altered climatic regime (Figure 7.4).

Assessments of the effects of climate change on rangelands in southern Africa are hindered by a lack of available data on the functioning of these complex ecosystems and the large uncertainties relating to the responses of plants and humans to an altered climate. In addition to global warming, changing social and political conditions will also play an important role in determining future rangeland productivity in SADC (Section 7.3).

Considering some of the consequences of climate change on rangelands in the SADC region, and the resulting effects on future national and subsistence economies, Hulme et al (1996) simplified their 3 scenarios (Section 2.5.2.3) into two broad types of environmental change that may occur. These are the ‘tropification’ scenario, resulting from increased temperatures and increased rainfall and the ‘aridification’ scenario, resulting from increased temperature and decreased rainfall. A broad summary of the possible effects on Namibian rangelands based on these ‘what if’ scenarios is depicted in Table 7.1. Concerns regarding the effect of increased aridification on rates of land degradation are discussed in Box 7.7.

**Box 7.7 INCREASED ARIDIFICATION AND LAND DEGRADATION**

[B. Strohbach pers.comm.; Le Houerou 1996]

Unless domestic cattle numbers are reduced and overgrazing prevented during dry spells, the rate of degradation of Namibian rangelands is liable to increase rapidly under a general aridification scenario.

Soil erosion is unlikely when the ground is covered by a dense stand of perennial grass. These grasses can survive up to two years of drought - provided they are not subjected to heavy grazing. This is because the energy reserves stored in their roots or underground stems which allow them to survive in the absence of rain, are drawn upon to create new growth each time the plant is grazed. Ultimately, the energy reserves may be totally depleted, preventing the rejuvenation of the plant once good rains return. This leaves the soil bare and highly vulnerable to erosion.

An aridification scenario will favour annual grasses over perennials – a situation that currently exists in the desert areas of Namibia. Annuals store energy in their seeds. Once they have produced and shed their seeds they can be fully grazed without affecting the next period of growth. During drought their ground cover is reduced considerably. These annual species have very short life cycles and are often inconspicuous for many years, only reappearing once good rains return.

### 7.4.3 Impacts of climate change on land degradation and desertification

As mentioned in Section 7.2.3, in the absence of sustainable land management practices, climate-related factors such as severe drought can lead to an escalation of the desertification process. It is not easy to separate the many interlinked effects of man-induced impacts on the soil from those that are climatically induced, but their interactions will ultimately have cumulative consequences (Figure 7.4).
Table 7.1 Namibian rangelands. A summary of the possible impacts of climate change [Adapted from Hulme et al 1996].

<table>
<thead>
<tr>
<th>IMPACT TYPE</th>
<th>ARIDIFICATION ('Core' and 'Dry' scenarios)</th>
<th>TROPIFICATION ('Wet' Scenario)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biome shifts</td>
<td>Reduced species diversity. Tree and scrub savannah of north eastern and north central Namibia are expected to change towards thorn scrub savannah. Annual grasses will be favoured over perennials – if the later are overgrazed during times of drought. Desert conditions are likely to encroach on the semi-arid central areas of the country.</td>
<td>Enhanced species diversity within savannahs accompanying increased vegetation cover. Extent of biomes unlikely to shift.</td>
</tr>
<tr>
<td>Sectoral shifts</td>
<td>Desert expansion in semi-arid areas will dramatically reduce the carrying capacity in some areas. Reduced cattle potential in favour of small stock and some wildlife species will occur. Reduced risk of livestock diseases could be accompanied by an increase in viability for livestock in some areas (eg. eastern Caprivi).</td>
<td>Little change, possibly better cultivation opportunities in some areas. The possibility of lowered nutrient content of grasses (increased fibre content relative to protein) would favour small stock and some wildlife species. Increased prevalence of some livestock disease vectors and other health problems is likely to occur.</td>
</tr>
<tr>
<td>Productivity and income by sector</td>
<td>Increase in marginal conditions, increased rates of erosion and woody weed expansion (bush encroachment) adversely affects productivity and income.</td>
<td>Little change, small increases in cultivation.</td>
</tr>
<tr>
<td>Livelihood Security/ Income Distribution</td>
<td>Reduced in most areas because of extreme events and marginalisation of conditions. Most dramatic impacts experienced amongst impoverished rural communities less likely to have the means for anticipatory action. Least affected are commercial farmers with large, healthy wildlife herds.</td>
<td>Reduced security: (more prevalent extreme events e.g. increased flooding and spread of pestilence and disease).</td>
</tr>
<tr>
<td>Development potential/Carrying capacity</td>
<td>A general decrease.</td>
<td>Unchanged or slight increase</td>
</tr>
</tbody>
</table>

Impacts of climate change on land degradation and desertification cont.
Arid and semi-arid land ecosystems have little ability to buffer the effects of climatic variability and are considered to be particularly vulnerable to climate change. Some of the expected effects of climate change on soil erosion and other forms of land degradation may be summarised as follows (Bullock and Le Houérou 1996):-
- Where conditions become more arid, evapotranspiration and capillary rise in plants will be enhanced and an increase in soil salinisation and alkalisation is likely; and
- Higher evaporation rates accompanied by drier conditions are likely to exacerbate wind erosion.
7.4.4 Livestock health and climate change

Most climate change scenarios suggest increased rainfall variability and more prevalent occurrence of drought. Observations on how drought currently affects livestock health offers some indication as to what can be expected if this scenario is realised.

- Drought lowers the availability of forage, reduces milk production, growth rates and health status of livestock. It results in increased mortality and lower prices for animals (Ashley and La Franchi 1997). Between 1990 and 1997 the loss of livestock in Namibia was predominantly due to the effects of drought (Appendix 11).

- After periods of drought, poisonous or other unpalatable plants are often the first to emerge, particularly on rangelands that have been overstocked or overgrazed. Feeding livestock have no choice but to graze off these species, increasing the chances of mortalities due to poisoning (Box 7.8 and Appendix 11).

- Drought impacts on rabies and other diseases in an indirect manner. Jackals and other scavenging animals become more prevalent around human settlements during dry periods, thus increasing the number of reported rabies incidents and the possibility of increased human and domestic animal infection (Dr. R. Paskin pers. comm.).

Multiple health impacts, including the unforeseeable emergence of new or resurgent diseases are possible as a result of climate change (WRI, 1998). Geographical shifts in vector borne diseases are highly likely – each vector likely to be affected individually by an altered climatic regime. The DVS identifies at least 14 vector borne diseases that currently afflict animal species in Namibia. Vectors include ticks, tamps, gnats, mosquitoes, flies and mites. Table 7.2 describes four southern African vector borne diseases and their possible responses to climate change.

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**Box 7.8 LIVESTOCK PLANT POISONINGS IN NAMIBIA**

[Sources: EEA 1994; DVS 1997; B. Kohrs pers. comm.]

The following plant species are known to cause considerable livestock mortalities on commercial farms in Namibia: *Urginea spp.* (Slagkopp); *Dichapetalum cymosum* (Gifblaar); *Geigeria spp.* (Vermeerbos); *Crotolaria spp.* (Stywesiektebossie) and *Tribulus terrestris* (Geeldikkop). The density of *D. cymosum* is reported to be increasing due to grazing pressure and excessive fires.
Box 7.8 cont.

Between August and October 1996 (a bad drought year) 42 farms in the Keetmanshoop district suffered from the effects of *Ornithogalum namodes* poisoning. These were the first reported cases of death by this plant and 759 goats and 2077 sheep died as a result. During 1997 (a year of good rain) a total of 1420 cattle, 4055 sheep and 1957 goats were reported to have died from various plant poisonings across the country.

### 7.5 Conclusions

Namibia’s agricultural sector is subject to uncertain output, regular crop failure and a drain on state finances through unsustainable subsidies and drought relief. Land degradation reduces the production potential of agricultural land and dependence on highly variable annual rains for crop production and rangeland recovery, makes the livelihoods of commercial and rural subsistence farmers extremely uncertain.

Expected ultimate effects of climate change on the agricultural sector in Namibia may be summarised as follows:

- **Geographical shifts in the areas suitable for agriculture could disrupt rural communities** – adding to food security stress, social instability and increased rates of urbanisation.
- **Under an aridification scenario**, changes in vegetation cover will significantly affect rates of soil erosion in semi-arid regions, particularly in the absence of sustainable rangeland management practices.
- **Altered primary production**, increased vulnerability to crop failure and reduced productivity from livestock due to increased bio-invasions, rising temperatures and variability in rainfall is likely to modify inter-regional food dependence and result in changes to national and international markets.

Thus, land use options, production profitability, poverty, employment potential and economic sector competitiveness are all likely to be affected by an altered climatic regime. However, as local farmers have lived under marginal conditions for decades, the overall consequences of climate change under a general aridification scenario are likely to be less for commercial farmers in Namibia than in other parts of SADC. For example, the partial replacement of cattle with either small stock or wildlife, which are better suited to marginal conditions, has already occurred on many Namibian commercial rangelands. Nevertheless, impacts on household food security in the subsistence farming areas could be dramatic and climate change has the potential to cause significant social disruption and population displacement amongst these communities. Recent CBNRM initiatives that have encouraged rural communities to form conservancies offer promising opportunities for more sustainable and productive resource management and more wildlife centred enterprises in some of these areas. However, most communal farmers are unlikely to easily make a shift away from large domestic stock farming, as cattle are valuable assets and play a vital role in their livelihood strategies.
Table 7.2 Some climate sensitive tropical livestock vector-borne diseases prevalent or potentially prevalent in Namibia [adapted from UNEP 1996; WHO/CTD 1998; Hulme et al 1996; B.Kohrs, pers comm.]

<table>
<thead>
<tr>
<th>DISEASE</th>
<th>PATHOGEN</th>
<th>VECTOR/RESERVOIR</th>
<th>Presence in Namibia</th>
<th>Presence in neighboring states</th>
<th>Possible change in distribution</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theileriosis</td>
<td><em>Theileria</em> spp.</td>
<td>V. Ticks, <em>Rhizophagus</em> spp.</td>
<td>✓</td>
<td>✓</td>
<td>+</td>
<td>The dominant climatic variable influencing <em>Theileria</em> sp. distribution appears to be temperature and a variety of subsidiary factors including cloud, wind and vapour pressure. Hulme’s ‘core’ scenario suggests a possible shift in the distribution of the vector into central Namibia, particularly the Khomas and southern Okonjandjupa Regions.</td>
</tr>
<tr>
<td>Bovine Anaplasmosis</td>
<td><em>Rickettsia</em> <em>Anaplasmia</em> marginale</td>
<td>V. Ticks <em>Boophilus</em> spp., <em>Dermacentor</em> spp. believed to be the most important, but flies, horse flies and several other tick species are also responsible for transmission</td>
<td>✓</td>
<td>✓</td>
<td>?</td>
<td>Currently prevalent in the northern communal areas. Disease flare-ups occur during good rainy seasons and it can be considered highly susceptible to changes in climate due to the large number of potential vectors. Can cause considerable economic losses through loss of condition and death. 36% of all cases (n=241) reported in 1997 were fatal.</td>
</tr>
<tr>
<td>Nagana (Sleeping Sickness)</td>
<td>Protozoan parasites <em>Trypanosoma</em> congoense and T. vivax</td>
<td>V. Tsetse fly, <em>Glossina</em> spp., R. Wild mammals</td>
<td>✓</td>
<td>Zambian, Eastern Caprivi, Eastern Angola, Northern Botswana.</td>
<td>-</td>
<td>The dominant climatic variables that affect the suitability of habitat for the disease vector, appear to be temperature and evapotranspiration. Capable of causing reduced productivity, increased mortality amongst cattle. All three of Hulme’s climate change scenarios suggest a possible future reduction in habitat availability for <em>G. morsitans</em> throughout the southern African region.</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>Parasitic worm <em>Schistosoma haematobium</em></td>
<td>R. Aquatic snails</td>
<td>seldom</td>
<td>All</td>
<td>++</td>
<td>Can cause severe morbidity in cattle. Reported from communities residing near to the perennial rivers in the north-east and north-west.</td>
</tr>
</tbody>
</table>
Conclusions continued.

Studies on the vulnerability of subsistence crops in Namibia should form the focal point of future investigations into climate change impacts on the country’s food security. In addition, Namibia’s increasing dependency on food imports should involve more than a passing interest in the expected changes within the region as a whole - particularly in those countries that are currently southern Africa’s major grain exporters.

**SOME RECOMMENDATIONS**

- Support all efforts to combat biodiversity loss and desertification at a national and regional level through sustainable and diversified economic development.
- Continue to offer incentives for shifting from domestic stock to wildlife ranching.
- In order to keep future irrigation schemes in perspective with Namibia’s present and future hydrological reality, it is essential that water and agricultural policy be integrated. Production subsidies for domestic livestock and low value crops should be avoided, and long term drought management, as laid out Namibia’s new Drought Policy must be encouraged. Low water use and high value per water use crops must continue to replace staple grains that demand large quantities of water with low return.
- Protection against present and future extreme events should be a priority. Improve monitoring and communication capabilities in order to enhance the responsiveness of the agricultural sector to forecasts of production variations and food crises.
- Prevent the contamination of Sanga cattle gene pools and encourage research, development and testing of new CO₂ responsive, heat and drought resistant crop cultivars.
BIODIVERSITY
8.1 The Importance of Biological Diversity

Humans evolved and survive today because of the existence of, and services provided by, other species of micro-organisms, fungi, plants and animals. These species, their genetic components and ecosystems that they form are collectively termed “biodiversity”.

Ecosystems that support a rich biological diversity and variety of trophic pathways and interactions, exhibit higher productivity, capture and retain resources more efficiently and display greater resilience to extreme environmental conditions, disease and pestilence. The wise management of biodiversity and the maintenance of complex ecosystems is of vital importance to human survival (Figures 7.2 and 8.1).

Figure 8.1 The Importance of Ecosystems

The estimated annual value of the Earth’s ecosystem services and natural capital is US$ 33 trillion or 1.8 times the global Gross Domestic Product (Lindsey 1998). Although it may not always seem obvious, all species are important and play a significant ecological role. For example the yield of many major food crops and wild flora are threatened by a global decline in animal pollinators including birds, bats, bees, butterflies and an estimated 1200 other wild species known to be at risk of extinction (Pearce, 1998).
The Importance of conserving biodiversity cont.

- Comparing the fate of agro-pastoralists in the Sahel with those in the Kalahari during the severe droughts of the 1980’s, Marsh and Seely (1992) highlight the fact that arid areas which still support a healthy biological diversity can act as a buffer against the ravaging effects of drought.
- Tilman and Downing (1994) have illustrated that the recovery of grasslands following a drought is more rapid in areas where greater levels of diversity have been maintained.
- In Namibia, where some rural communities rely on wild products for at least 50 % of their sustenance1 (Ashley and La Franchi 1997), the ability to avoid widespread malnutrition and maintain self-reliance is closely linked to the maintenance of the country’s ecological systems.
- The economic value of non-agricultural land-use in northern Namibia has been evaluated by Barnes (1995) and shows that losses in biodiversity will exacerbate an already declining rural economy. Large gaps in knowledge make it impossible to assess the exact economic value of all species, however Namibia’s National Biodiversity Task Force (NNBTF) has compiled a rudimentary list of examples of species that are known to have economic importance in Namibia (Appendix 8).
- Tourism, Namibia’s most promising sector, draws heavily on the country’s healthy wildlife populations, diverse habitats and dramatic landscapes (Box 8.1).

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Box 8.1 NAMIBIA'S TOURISM INDUSTRY
[Source: Barnard,1998; Commission of Enquiry into Gambling 1997, unpub. report]

The tourism sector has expanded by an estimated 8-10% per annum since the early 1990’s. A survey conducted in 1997 showed that almost all tourists visiting the country expect an environment-centred experience – either through game viewing, bird watching, hiking, sport fishing or trophy hunting. These wildlife-based activities contributed an estimated NS200 million value added to Gross Domestic Product in 1992. Recent estimates suggest that 20 000 jobs are currently created either directly or indirectly through the tourism industry – accounting for an estimated 15% of private sector employment. The export of game and related products, fish and travel services currently accounts for 1-2%, 4% and 14% of total exports respectively.

Presently, one third of all foreign tourists to Namibia are from South Africa, one third from Germany and the remaining third is comprised of a mix of other nationalities. A greater percentage of North American tourists is expected in future. Namibia’s Tourism Development Plan predicted that 540 000 foreign tourists annually by the year 2000 and gross foreign exchange earnings of NS1 billion. However this had already been achieved by the end of 1997.

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1 These figures are valid for Caprivi. At a national level it is estimated that 33% of total household consumption comes from wild foods (CSO, 1995). Households in the Omasati, Oshangwena, Oshikoto and Okavango regions are the most dependent on wild products while those in the Hardap, Erongo and Karas regions are the least dependent (Barnard, 1998).
8.2 Brief overview of Namibian Biological Diversity

In May 1998, Namibia’s National Biodiversity Task Force (NNBTF) completed the first comprehensive study on biological diversity in Namibia (Barnard, 1998). Unless otherwise stated, all information mentioned in the following a section has been extracted from this source.

8.2.1 Terrestrial Ecosystems

Namibia’s three main vegetation biomes, viz. Desert, Savannah, and Dry Woodland, are briefly described below. These broad biomes are divided into 14 vegetation types (Fig 8.2). Temperature, precipitation patterns, topography and soil influence distribution and carrying capacities of these vegetation zones. Most of Namibia’s soils have low nutrient value or are highly saline.

• **Desert.** 16% of the total land area is hyper-arid or arid desert receiving <100 mm of rain per annum. The hyperarid zone covers the entire western coastal plain and southern Namibia. Species richness in the Namib sand seas is limited by low rainfall and the instability of the substrate. It is highest along the ephemeral river courses, on inselbergs and on the more stable gravel plains and rocky hills south of Luderitz. Coastal fog (Section 2.1.2) plays a major role in supplying moisture to arid adapted plants and animals in areas where virtually no rain falls. Species encountered in the Namib Desert display a high degree of endemism and specialisation. Most of these endemic species are arid adapted and associated with escarpment, inselburg or dune habitat (Simmons et al 1998). The following areas have been identified as important hotspots:
  - The succulent steppe vegetation belt (Figure 8.1) which falls within the Sperrgebiet and receives small amounts of additional rainfall during the winter months. This area supports a high degree of endemic succulent plants, reptiles and invertebrates (Simmons et al 1998).
  - The narrow, poorly defined Namib escarpment which forms a transition zone between the Namib desert and the central highland plateau (pro-Namib zone). This semi-desert/savanna zone supports many endemic plant, invertebrates, amphibian, reptile, mammal and bird species.

• **Savanna.** 64% of the total land area is arid to semi-arid savanna which receives 100-400mm of rainfall and covers the central and north central plateau, is dominated by acacia species and supports a diverse plains wildlife community.

• **Dry sub-humid woodland.** This covers approximately 20% of the total land area and occurs in the wetter northeast which receives between 400-700mm of rainfall per annum. These areas are dominated by deciduous broad-leafed species and support the highest wildlife biomass and species richness. The higher species richness in this area is attributed to the presence of large, perennial tropical river systems e.g. the Okavango, Kwando, Kunene and Zambezi rivers and their associated riparian habitats.

8.2.2 Wetlands

Wetlands cover approximately 4% of Namibia. These include coastal lagoons, ephemeral pools, pans and rivers, springs, the Oshanas of northern central Namibia, perennial
sinkholes in the Karstveld, the perennial rivers along the country’s borders and their associated floodplains (Figure 5.1). Collectively these wetlands are described as Namibia’s most productive and biologically diverse ecosystems supporting many plants, crustaceans, amphibians, reptiles and birds. Of the 57 geothermal (hot water) springs that occur in Namibia, the three hottest, Ai-Ais, Gross Barmen and Rehoboth, have been developed as tourist resorts.

The majority of Namibia’s human population depend on resources supplied by wetlands. These include water, fish, vegetation for grazing, thatching, basketry, crops, herbs, trees for fencing and fuel, clay for pottery, wildlife for subsistence and attracting tourists. Namibia’s coastal wetlands include three Ramsar sites (Sandwich Harbour, the Walvis Bay lagoon and the Orange River mouth). These sites provide valuable nursery areas for certain coastal fish species (H. Holtzhausen pers. comm.) and productive feeding grounds for vast flocks of palaeartic and resident wading shorebirds (Section 9.1).

In addition to enhancing human livelihoods and conserving biodiversity, wetlands and their accompanying vegetation support essential ecological processes through water purification, streamflow regulation and nutrient recycling (Figure 5.1(a) and Section 5.4.2).

8.2.3 Marine and coastal ecosystems

The country’s coastal ecosystem, the Benguela, supports one of the highest concentrations of marine life found anywhere in the world. Typical of all upwelling systems, the Benguela is inherently unstable and displays continuous variation. This natural variability (Box 6.1 and Figure 6.1) has favoured generalist feeders (Sakko 1998). Species richness in all of the Benguela’s habitats (including the sandy beach, rocky shore, reef, slope and abyssal habitats) is relatively low but in most cases is accompanied by very high biomass. No marine endemics are known to occur specifically in Namibia but several endemics occur in the ecosystem as a whole (ibid).

Namibian marine diversity displays a clear trend of decreasing species richness from the south to the north – an anomalous trend when compared with most other parts of the world where biodiversity generally increases from the poles toward the equator (ibid). Despite falling within subtropical latitudes, the cold Benguela is inhabited by organisms usually associated with sub-polar climes.

Namibia’s marine resources and coastal zones are discussed in more detail in Chapters 6 and 9 respectively.

The loss of species impairs ecosystem functioning, ultimately increasing vulnerability to extreme events. Consequently, the resilience of ecosystems to the effects of global warming will largely be determined by the many human-induced factors that currently result in a loss of biodiversity or threaten the maintenance of natural systems. These factors include pollution, land degradation and those policies that dictate changes in land-use and ultimately determine the size and nature of the areas that are left in an indigenous state – be they large or small, scattered or well-connected. In an attempt to provide some insight into the sensitivity of local

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2 An economic ecosystem evaluation reported in the journal Nature (May 1997) estimates that the services and goods provided by the world’s terrestrial wetlands are valued at US$ 4.9 trillion annually (Lindley, 1998).
8.3 Biodiversity loss in Namibia

8.3.1 Causes of biodiversity loss
Ecosystems world-wide are being altered irreversibly. Habitat destruction is undoubtedly the most important process threatening global biodiversity and current rates of regional and global species extinction are reported to be several orders of magnitude faster than at any other time in human history (IGBP 1996). Land degradation (Section 7.2.4) and land clearing are the most important causes of terrestrial biodiversity loss in Namibia but a lack of pollution control, overexploitation of certain species, inadequate conservation measures outside protected areas, conflicts between people and wildlife and illegal hunting are also directly responsible for the depletion of wild fauna and flora in the country. The indirect causes of biodiversity loss are closely linked to unsustainable economic development and the formation of inappropriate policies (Box. 8.2).

Box 8.2 ECONOMIC AND POLITICAL CAUSES OF BIODIVERSITY LOSS [Sources: Dewdneys 1996; Richardson 1998]

Global patterns of biodiversity loss are directly linked to the fact that:

- Biological resources are not given appropriate prices in the market place;
- The benefits of protecting natural areas are seldom represented in economic decision making;
- Those who reap the benefits of resource exploitation are often not those who bear the costs;
- There is a trend towards the breakdown of traditional systems of common property in which resource use is regulated by community structures;
- Economic growth is often built on short-sighted decisions and the unsustainable use of resources resulting in depletion and degradation.

Namibia has produced many policies that inadvertently counteract sustainable development and the sustainable use of water, land and wildlife. These include livestock subsidies, drought aid, inappropriate price support for commercial maize and wheat producers, unrealistic pricing policies and the lack of property rights in communal areas. Although efforts are beginning to be made to address most of these issues, their continuation will exacerbate poverty, cause increased pressure on wild habitats and increase Namibia’s vulnerability to drought.

Additional causes of biodiversity loss, which are likely to increase in the future include the following:-

- Alien species that invade ecosystems can result in decreased ecosystem stability and the loss of native species. Disturbed ecosystems are particularly susceptible to invasions (Walker and Steffan 1997). Although Namibia has comparatively minor problems with alien invasive species, some are considered to be of economic and ecological concern. Areas most affected are those close to human settlements and
rivers (both perennial and ephemeral) where alien plants can have a damaging effect on catchment management and water supply. Infestations of alien plants can cause crop losses and livestock poisoning. Although arid zones are fairly resistant to alien invasions, future increases, particularly along perennial and ephemeral river courses, could occur due to trends in landuse/vegetation cover change, increased globalisation of trade and increased ecological disturbance. Namibia has no national policy or programme on the introduction of alien species. In order to be fully effective, a regional policy or law for the entire SADC region is necessary.

- In addition to the well publicised poaching of rhino and elephant, illegal trade in many of Namibia’s succulent plant species, insects, reptiles and unusual small mammals like pangolins is believed to be considerable (in Barnard 1998). Control over the commercialisation and/or export of these species needs to be improved considerably as their unsustainable illegal harvesting can pose a serious risk of local extinction of many species.

- The effect of pollution is not yet widespread in Namibia but does have a localised effect in some areas. In the north central and north east of the country pesticides, sprayed directly onto standing water to control malaria, and the use of biocides by the agricultural sector are expected to result in the localised extinction of certain frogs and other organisms that feed on aquatic invertebrates and agricultural pests. Pollution from fertilisers used in the Hardap Irrigation Scheme has entered the basin via the Fish River adding to the threats in this area (Kohler 1997). Marine pollution is increasing with increased traffic through Namibian ports (Section 9.2).

- Water transfer and storage schemes in Namibia incur heavy environmental costs (Table 5.4) and the potential threat posed by the establishment of the Okavango extension to the ENWC is of concern to both Namibian and Botswanan environmentalists (Section 5.6.2). Since its completion 12 years ago, the open canal section of the ENWC has been criticized for inadvertently causing the death of vast numbers of wild animals. These mortalities include a minimum of 50 000 reptiles per annum (Griffin 1998). Regulation of perennial river flow by dams and weirs directly threatens fish diversity. This already occurs in the Kunene river as a result of the existing Ruacana division weir and the situation is likely to deteriorate if the proposed Epupa Dam is built. The establishment of the Lesotho Highlands Hydro Scheme is expected to reduce fish populations and threaten the livelihoods of fish and birds at the Orange River mouth (in Barnard 1998). Dams on ephemeral rivers seriously alter the frequency of river flow and the recharge of coastal aquifers. They have a detrimental effect on downstream riparian vegetation and wildlife (Jacobson et al 1995; Section 5.4.2). Several new dams are planned to help alleviate water shortages in Windhoek and at the coast.

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3 The Orange, Fish, Kuiseb, Omaruru and Ugab rivers and areas around Windhoek, Katimo Mulilo and Waterberg are currently the most noticeably invaded areas.

4 Namibian dwarf pythons dwarf adders and tortoises are particularly popular with dealers in the illegal pet trade. All Namibian tortoise species are currently threatened (Griffin 1998)

5 A yield analysis of the proposed Donkersau dam on the Kuiseb catchment shows that if this dam is built it will affect downstream flow and frequency dramatically. 10 Mm$^3$ of flow is required for the Kuiseb to recharge coastal aquifers. Results show that the number of years with 10 Mm$^3$ or more flow would fall from 1 year out of 2.1 to 1 year out of 7.9 if the dam is built (Mostert 1998).
8.3.2 Trends in biodiversity loss

It is not currently feasible to accurately assess Namibia’s rate of biodiversity loss. However, Boxes 8.3 and 8.4 give an indication of recent trends in some areas and highlight what is expected in others, unless preventative measures are taken. Namibia’s natural wetlands and their accompanying flora and fauna are considered to be the country’s most threatened ecosystems. A brief overview of some taxa is given in Section 8.3.2.1. This information, although incomplete, offers some indication of national biodiversity health. Endemic, red data, keystone and umbrella species have been identified as the country’s most ecologically important organisms.

Box 8.3 LOSS OF BIODIVERSITY IN NAMIBIA’S NORTHERN COMMUNAL AREAS
(Source: Marsh and Seely, 1992; Ashley, 1996; Mendelsohn and Roberts 1997)

Since the 1950’s extensive mopane woodlands and large mammal species including zebra, gemsbok, elephant, springbok and wildebeest have almost completely disappeared from the Omusati, Oshana, Ohangwena and Oshikoto regions in northern Namibia. Human induced vegetation changes in these regions have resulted in noticeable changes in biodiversity and species composition. Non sustainable use has caused considerable reductions of woody vegetation, mainly Terminalia sericea and tall thatching grass from oshana drainage lines. Edible fruit bearing species like palm, marula and Diospyros sp. tend to be protected in agricultural fields but even some of these are threatened. Palm leaf stems and fruit are becoming increasingly important as a source of fuel especially in heavily deforested areas. The presence of alien invasive plants mainly Nicotiana glauca and Flaveria bidentis, are prevalent around houses, along roads and around water points.

If current rates of land clearing in the Caprivi continue, it is estimated that all land in this region, whether suitable for crop production or not, will be cleared by the year 2082. As the Caprivi supports the country’s highest wildlife biomass and species diversity, this extensive land clearing will be accompanied by biodiversity loss and changes in species composition similar to those mentioned above.

8.3.2.1 Brief Overview of the Current Status of Some Taxa in Namibia

Only a small number (possibly as little as 20%) of Namibia’s species have been described to date. Of the 13 637 species that have been described, almost 19% (2557) are endemic. A breakdown of the percentage of known endemism for the major taxa is shown in Appendix 6. This high degree of endemism reflects the biotic uniqueness of Namibia and the Namib Desert and pro-Namib transition zone in particular.

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6 Red Data species are either endangered, threatened or vulnerable. Keystone and Umbrella species are those for which conservation measures have a significant impact on other biota in the same habitat. Knowledge concerning these important species in Namibia is scant.
7 Only some taxa are well researched (e.g. birds, mammals). Others have been neglected and require extensive research (e.g. bacteria, rotifers, nematodes, soil arthropods, algae and mycorrhizal fungi).
8 Endemic species are broadly described as being “unique and occurring nowhere else”. However, this term is used inconsistently. While ornithologists describe a bird as endemic if 90% of its range falls within the country, botanists require that 100% of a plant’s range must fall within the country’s political boundaries for it to be considered endemic.
• **Fungi** play a fundamental role in ecosystem functioning and their economic importance is immense. Research into this taxon in Namibia has been neglected and best studied species are those of known economic importance (Appendix 8). No endemic fungi are yet known and their conservation status cannot be determined without improved biogeographic and ecological data.

• The unsustainable use of **plants** directly threatens the maintenance of ecosystems and the subsistence economies of Namibia’s poor majority (Figure 7.2). The need for effective plant conservation is fundamental to helping combat land degradation in an arid country like Namibia (Section 7.2). At present 266 plants (6% of the known species) have been assigned Red Data status. However, this is not necessarily a true indication of endangered plants as many, including most of Namibia’s endemics, have not yet been reviewed for conservation status.

• Loss of **insect** diversity in Namibia’s savannas and woodland will threaten the essential processes on which these ecosystems depend. Namibia supports a highly distinctive, endemically rich insect fauna and the current conservation status of this taxon is considered to be fairly good. Those species confined to aquatic or riverine habitats are the most threatened in the long term. Arachnid fauna is essentially arid adapted and fairly species rich but their conservation status is generally unknown due to the lack of data on their ecology, taxonomy and distribution.

• **Freshwater fish** biodiversity in Namibia is threatened by overexploitation by subsistence fisheries, the translocation of species from one basin to another, increased hydrological regulation of rivers and the loss of riparian vegetation. Between 1992 and 1994 there was a decline of almost 50% of fish caught using traditional methods as many subsistence farmers have begun to replace traditional fishing baskets with extremely fine mesh nets and other modern equipment. Six red data freshwater fish have been identified for Namibia and all endemics are considered to be endangered (See also Box 5.1(a)).

• **Amphibia.** Twenty-six (50%) of Namibia’s frog species are considered to have secure conservation status but all 20 species that are dependent on perennial waters can be considered vulnerable.

• Most of Namibia’s **reptiles** are arid adapted and reach their highest richness in the country’s northeast. 167 (67%) Namibian reptile species are currently considered to be of conservation concern and the lack of formal protection of many endemics poses a constant threat. Crocodile farming and strict control since the 1970’s, when these large reptiles were overexploited for their skins, has helped to save this species from local extinction.

• **Birds** are the best researched faunal component in Namibia and are the only taxon for which indices of diversity have been applied. Detailed analysis of conservation

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9 Mycorrhizal fungal diversity has been used to monitor ecosystem integrity under the threat of global climate change in Europe and to distinguish human-induced degradation from natural climate stress in Namibia. Economically fungi are globally important - especially in the fields of human and animal medicine and crop pathology (Manheimer and Jacobson 1998).

10 Termites and beetle larvae dominate the soil fauna in arid environments and termites and dung beetles are possibly the most important decomposers on Namibia’s savannas.

11 Fish stocks in the Okavango river in particular have deteriorated significantly since 1984 due to both overexploitation and devegetation. Biologists report that, even if overexploitation of the fish is curtailed, it will be difficult for the depleted fish populations to recover due to the loss of habitat.
priority areas has been made possible by geo-referenced databases. 86 (13%) bird species are considered to be threatened\textsuperscript{12} at the national level and wetland habitats contain the greatest number of threatened species. All species of scavenging birds of prey (vultures and some eagles) and most non-scavenging raptors are at risk in Namibia due to poisoning by farmers and by shooting.

Over 50\% of the bird species that are restricted to the riparian belt habitats are threatened in Namibia. This figure reflects the environmental degradation occurring in these habitats due to increased human population pressure and habitat destruction by elephant in some protected areas. Eight coastal birds (20\% of all coastal birds) are classified as threatened. Ornithologists have identified 21 areas as Important Bird Areas (IBAs) in Namibia – 8 of which currently have no protected status.\textsuperscript{13}

- Namibia's marine organisms are well adapted to the fluctuating conditions that are a natural part of the Benguela system. However, exceptional conditions such as those that prevail during Benguela Niños (Box 6.1) are capable of causing extensive mortalities of many marine organisms (Sakko 1998). In addition to the natural variability of the ecosystem, threats to Namibia’s marine and shore life, include the over exploitation of fish stocks and many other human activities (Figure 6.1 and Section 9.1).

Most commercially exploitable species have shown a noticeable decline in recent decades and, although there are no recorded extinctions of fish species in Namibian waters, many populations have experienced population crashes (Sakko 1998). Heavy exploitation of certain species eg. pilchard and anchovies have added to the stress placed on them due to the Benguela's natural variability. As a result, these species are certain to display reduced heterozygosity (genetic impoverishment), which will limit their chances of surviving future environmental stresses.

- Mammals. Due to increasing trends in wildlife based industries (Section 8.4) Namibia still supports large, healthy populations of certain species, many of which are threatened in other countries. Currently, more than 90\% of all large mammals are found outside formal conservation areas\textsuperscript{14} but data on the biogeography and conservation status for most species (particularly the rich fauna of small, lesser-known mammals) are poor.

Approximately 100 (50 \%) of Namibia's mammal species are provisionally considered to be of conservation concern and in recent historical times some species have experienced noticeable range reductions\textsuperscript{15}. Sixteen (8\%) of Namibia's known mammal species have been assigned definite threat categories\textsuperscript{16} but only a few of the larger species (including those that enjoy secure conservation status) have been the focus of research efforts\textsuperscript{17}. The 10\% of all mammal species that are either dependent

\textsuperscript{12}The term threatened covers the following categories: critically endangered – species in danger of extinction; endangered – species likely to move into the critical category if causal factors continue to operate; vulnerable – species with small localised and declining populations.

\textsuperscript{13}The identification of IBAs's helps to protect the most important areas for birds in each country through the prioritisation of conservation efforts. Ichaboe, Mercury, possession and the Luderitz Bay islands are included amongst the 8 areas that are currently given no protected status.

\textsuperscript{14}About 80\% and 9\% of the larger game species are found on privately owned commercial farms and communal areas respectively.

\textsuperscript{15}In particular the plains zebra Equus burchelli and lion, Panthera leo.

\textsuperscript{16}Included amongst these are black rhino, cheetah and wild dog.

\textsuperscript{17}For example, economically valuable springbok, kudu and gemsbok.
on, or restricted to, wetlands are ultimately at risk due to the lack of conservation in many of these habitats.

Namibia’s marine mammals suffered tremendous overexploitation in the past. Although now granted protected status by the MFMR (with the exception of seals), populations of many of these species have yet to recover.

Box 8.4. NAMIBIAN SEABIRD POPULATION DECLINE (Source: Cordes:1998)

Until the mid 19th century Namibia’s 15 offshore islands and rocks were a safe haven for vast populations of breeding seabirds. Overexploitation of seabird guano and penguin eggs, which began after the 1840’s guano rush, initiated a rapid population decline of most of these species. Since the 1950’s a scarcity of food resulting from increasing human exploitation of fish stocks and oil pollution by damaged tankers or ships cleaning their tanks at sea, has also impacted heavily on seabird populations. Furthermore, populations of breeding kelp gulls, which prey heavily on the eggs and chicks of other seabirds, have increased significantly on Namibia’s offshore islands. As a result, many of Namibia’s seabird species are threatened and, without proper management and strict conservation methods, could face extinction.

Of the 7 species that breed on the offshore islands, African penguins (listed as critically endangered in the Namibian draft red data book) and Cape gannets (listed as endangered), have displayed the most dramatic decline this century.

### NAMIBIAN POPULATIONS OF TWO RED DATA SEABIRD SPECIES

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<tr>
<th>SPECIES</th>
<th>Estimated Population</th>
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<tr>
<td>Cape gannet (<em>Morus capensis</em>)</td>
<td>No data</td>
</tr>
<tr>
<td>African penguin (<em>Spheniscus demersus</em>)</td>
<td>500 000 – 700 000</td>
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8.3.3 Challenges facing biodiversity conservation

8.3.3.1 Parks and Protection

Namibia’s reserves are comparatively large and in most cases are surrounded by communal and commercial farmland. Some of these areas are under increasing pressure to be used for emergency grazing or reallocation due to land reform.

Protected areas in Namibia were not designed for biodiversity conservation and, as a result, the country’s ecological diversity is not evenly represented within the 13.8% of the land mass that represents the country’s protected areas network (Figure 7.1). Protected areas incorporate only nine of the 14 vegetation types described in Figure 8.2 and, although 30% of the Namib Desert biome falls within protected land, only 8-9%, 7-8% and 1-2% of the Woodland, Savannah and Karoo biomes respectively are currently protected (Barnard et al 1998).

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18 Namibia’s mountain savanna, thornbush savanna, highland savanna, camelthorn savanna, mixed tree and shrub savanna have virtually no representation within the protected areas network. Only 1.9% of the dwarf shrub savanna, Namibia’s second most predominant vegetation type, is represented within protected areas (Barnard et al 1998)
Rivers and riparian vegetation within the SADC region act as important natural corridors, especially for avifauna and wide ranging large mammals. Virtually all wetlands, although identified as the country’s most threatened resources, are severely underprotected as are many of the centers of floral and vertebrate endemism. Namibia has no proclaimed marine reserves.

In response to these challenges the NNBTF has identified several biogeographical categories and underprotected sites of special value (Appendix 9) that should form the focus of future conservation efforts and research activities. Four regions which support a high degree of endemic plants and animals (the Kaoko escarpment, the Succulent Karoo, the extinct volcanic crater Brukkaros and the Brandberg massif) have been identified as top priority areas for urgent biodiversity protection measures (Simmons et al. 1998).

8.3.3.2 Research Constraints
A large number of gaps exist in both information and action with respect to biodiversity conservation in Namibia. Although the government institutions involved with research are committed to improving the knowledge base, a lack of trained manpower, inadequate financial resources and poor coordination and planning, restrict progress in improving biological diversity information in Namibia.

Extensive research is carried out by the MFMR on the marine environment but this is almost entirely focused on commercially viable species. As a result, knowledge pertaining to the existence and maintenance of Namibia’s marine biological diversity at the species, community, habitat and ecosystem level is limited (Otte, 1998).

8.4 Positive economic trends in wildlife utilisation
There is tremendous optimism regarding the potential profits, growth and sustainability that can result from future wildlife based industries in Namibia. Tourism in particular has been targeted as a key growth sector within the economy and, if managed wisely, could provide a valuable foundation for the maintenance of terrestrial biodiversity.

8.4.1 Trends on Commercial Farms
Public participation in big game conservation was triggered in 1967 when legislation conferred ownership rights over certain game species to private (commercial) farmers. The positive spin-offs resulting from this decision were:

- The development of trophy and sport hunting, meat production through night-culling, live-game and tourism industries.
- An estimated 80% increase in the number of animals and a 44% increase in the number of game species found on private land over the period 1972 – 1992.
- Greater security for farmers. Wildlife generally utilise water more efficiently than domestic stock – displaying lower drinking frequency and consuming less water per day. Unlike cattle, wildlife species, especially springbok, wildebeest and zebra, are able to migrate vast distances for water without losing condition. Furthermore they are more tolerant of saline water and can feed off a wider variety of vegetation (Auer

19 Including the MET, the National Museum of Namibia and the National Botanical Research Institute.
By diversifying into mixed game/livestock farming, farmers reduce risks and create a valuable buffer against drought.

Concern is sometimes expressed that current game ranching methods restrict game movements, encourage inbreeding, lead to the overstocking of some species at the expense of others and should not be seen as the same as investing in the conservation of habitats and biodiversity (Dalal-Clayton, 1997). In Namibia, wildlife based enterprises have increased the amount of land allocated to wildlife and have helped to conserve certain key species for sustainable use. Neighboring farmers have begun to form large commercial conservancies by removing the fences between their properties. This allows greater freedom of movement for wildlife and counteracts inbreeding of herds.

Table 8.2 highlights the fact that the economic value of wildlife is expected to keep growing over the next 10–15 years and, as a result, some wildlife habitats and populations will continue to benefit.

Table 8.2. The growing value of wildlife on commercial farmland
(adapted from Ashley and Barnes, 1996)

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<td>NS million</td>
<td>31</td>
<td>56</td>
<td>112</td>
<td>5%</td>
<td>11%</td>
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8.4.2 Trends in the Communal Areas
The general approach to wildlife management and conservation on communal land has been “top-down”, with the state owning wildlife and enforcing legislation. This approach denied user rights of wildlife resources by local communities and created a negative conservation ethic. It also intensified human conflicts with wildlife, particularly in areas near proclaimed parks.

In spite of the fact that extensive deforestation and the noticeable disappearance of most wild mammals has occurred in the Omusati, Oshana, Ohangwena and Oshikoto regions (Box 8.3), other communal areas, particularly Caprivi and the Tsumkwe, Opuwo and Khorixas districts, still support healthy game populations. Tourism enterprises that have made use of these areas have developed in an ad hoc manner and optimisation of economic benefits has not been achieved. Local residents have received very little return from these activities and many perceive wildlife, especially elephant and large predators, not as potentially valuable resources, but as pests that cause considerable damage to crops and livestock.

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20 At the time of writing, six commercial farm conservancies had been formed.
21 Wildlife utilisation includes non-consumptive tourism (game viewing, ecotourism, photo safaris, education) and consumptive tourism (trophy hunting, small-scale hunting, live game dealing, game products including meat and skins).
22 Non-consumptive tourism accounts for N$15-20 million and consumptive uses account for N$32-37 million.
In 1994 43% of the communal areas contributed an estimated N$ 7.5 million to the net national income through wildlife utilisation – an amount that could easily have more than doubled to N$ 16.5 million if the existing resources were used to their sustainable potential (Ashley and Barnes, 1996). In 1994 residents of the northwest and northeast communal areas earned an estimated N$ 2.1 million from wildlife enterprises. Wages of local residents working in game lodges accounted for 50% of this amount and sales from handmade crafts accounted for 25% (Ashley and Barnes, 1996).

Prime areas for the most profitable eco-tourism developments fall within communal land and, if the right conditions are created, there is the potential for several-fold increases in the future. Through its Community Based Natural Resource Management (CBNRM) Program the GRN, in close co-operation with various NGOs, is encouraging rural communities to form conservancies (Section 8.4.3). The communal conservancy system aims to distribute the benefits from wildlife use and tourism enterprises in communal areas to the local communities involved. Besides improving living standards in the most marginalised areas of the country it is clear that these ventures will have tremendous spin-offs by supplying a buffer against the effects of drought through diversification, helping to conserve natural habitats and biodiversity, and reducing some of the negative effects of agriculture.

8.4.3 Trends in Protected Areas

It is difficult to accurately assess the real value and economic contribution of wildlife in Namibia’s protected areas (Ashley and Barnes 1996). These resources are used directly for tourism, capture of wildlife for restocking in other areas, live sale, research and education. Indirect and non-use benefits from these areas include the role they play in maintaining essential ecological functions and preserving biodiversity. Although accommodation facilities in national parks are reported to be running at a loss (in Barnard 1998), world renowned parks like Etosha and the Namib-Naukluft drive Namibia’s tourism industry and if run efficiently, should produce a substantial profit for reinvestment in wildlife management. They attract international visitors to the country, add value to adjacent areas which are also able to benefit from the tourist trade and indirectly boost many other supporting services and facilities (Ashley and Barnes, 1996).

8.5 Current Policy and Action

General policies and programmes

- Namibia is party to the UN Convention on Biological Diversity which stipulates the importance of conserving species at the local, regional and global levels and provides some generic guidelines for the achievement of this goal. In response, Namibia’s Conservation of Biotic Diversity and Habitat Protection Policy of 1994 was developed. This policy attempts to ensure adequate protection of all species, ecosystems and ecological processes through intersectoral research, education, ecosystems and ecological processes through intersectoral research, education,

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23 In some cases, the dispersal of wildlife populations onto neighbouring commercial or communal land occurs, creating a free-ranging asset that can be utilised outside the park boundaries.
24 Restaurants, taxis, airlines services, tour operators, craft producers etc.
legislation, land and natural resource management and cooperation with local, national and international organisations working for biotic diversity and habitat protection. The country study recently completed by NNBTF will lay a valuable foundation for future research and other activities (Appendix 10).

- The NNBTF’s Terrestrial Biomonitoring Working Group has begun to monitor and analyse environmental change in Namibia (combining research on biodiversity, desertification and bush encroachment) at an integrated multidisciplinary level. The NNBDF Wetlands Working Group and a Marine/Coastal Working Group, under the joint auspices of Namibia’s Biodiversity Programme and BCLME, are planning parallel efforts.
- Namibia’s new Environmental Management Act (EMA) specifies that environmental issues must be properly considered in the development of all future policies, plans, programs and new legislation. This environmental assessment exercise offers opportunities for preventative management and will help to avoid future damage to Namibian ecosystems and resources supporting human livelihoods.
- The DF has begun a quantitative assessment of forest resources that will aid in the development of an important database for forestry, biodiversity, desertification monitoring and future climate change monitoring.

**Pollution Control**

- Namibia’s legal system gives low priority to waste management and pollution control. National legislation in this regard is divided between six Ministries which have no uniform standards or co-ordination. Windhoek is the only urban center that has attempted to provide facilities for the separate disposal of hazardous waste. The DEA is in the process of establishing a National Waste Management Programme through which a national policy on pollution and hazardous waste management will be developed. In addition, the EMA attempts to prevent activities that can severely threaten the country’s biodiversity and ecosystem health by: - banning the importation of nuclear, hazardous or toxic waste into the country, stipulating clear polluter pays and prevention of pollution at source principles, and controlling the import and perpetuation of potentially invasive alien organisms.

**Land-Use**

- In 1996 Namibia’s Wildlife Management, Utilisation and Tourism in Communal Areas Policy was developed. This was followed by the Nature Conservation Amendment Act of 1996 which ensures that communal landholders are able to acquire common property rights over wildlife resources on their land. The first 4 conservancies gazetted have placed 2.25 million ha of land under conservancy ownership and this is expected to double in the near future. If successful, these efforts will help to conserve natural habitats and biodiversity in areas otherwise offered limited or no protection.
- Environmentalists in southern Africa are beginning to call for the establishment of transboundary environmental and natural resource management approaches. Amongst these are larger, more viable cross-boundary conservation areas. Figure 8.3 depicts four areas of potential cross-border tourism and wildlife management between Namibia and her neighbours. Of these, two require special mention.
In Caprivi, most wildlife herds migrate seasonally into neighbouring Botswana, Zimbabwe, Zambia and Angola and must be considered as valuable shared resources. The successful conservation of this entire area, and thus the ultimate
survival of its booming tourism industry, will depend on the establishment of a
cross-boundary conservation zone linking unspoliled habitats and some of the
established parks in these five countries (Mendelsohn and Roberts, 1997).

As a result of Namibia’s high security diamond mining operations, some habitats
within the unique Sperrgebiet have been well protected for more than 80 years
(figure 9.1). This area covers approximately 26 000 km² of desert and succulent
steppe terrain (Figure 8.2) which support a wide variety of landscapes and a
surprising wealth of unique and locally endemic plant and animal life. Diamond
mining in much of the Sperrgebiet is being downscaled and the fate of this area is
uncertain (Pallet 1997). The MET has initiated negotiations with the MME,
MLRR and MFMR in order to consider viable land use options for the
Sperrgebiet. These negotiations could result in the proclamation of a new park
which, when linked to the Ai-Ais/Huns Mountain Game Reserve in southern
Namibia and the Richtersveld National Park in South Africa, will form a link
along the entire west coast of Namibia, connecting the Namib/Naukluft Park, west
coast recreation area and the Skeleton Coast Park into Iona National Park in
Angola. If this occurs, it will make an internationally significant contribution
towards biodiversity and habitat conservation in the region.

8.6 Ecosystems and Climate Change

*Climate directly determines the nature and functioning of ecosystems. Changes in
climate result in several responses over a broad range of temporal and spatial scales –
from the almost immediate physiological responses of individual species, to the large-
scale geographic shifts in biomes over decades and centuries, and the incremental
changes in the genetic makeup of populations over millennia (UNEP 1996).*

Of the many impacts that will accompany global warming, increased concentrations of
CO₂ and higher temperatures are the most predictable and discernable (Section 2.5).
These factors alone are capable of causing considerable changes to the primary
productivity of terrestrial and marine ecosystems. Although the response of individual
primary producers (plants) to the effects of elevated CO₂ are difficult to ascertain (Box
7.5), a sustained increase in mean ambient temperature beyond 1°C is capable of causing
significant changes in species distribution, composition and migration patterns (Box 8.5).

Although natural climate change and accompanying changes in ecosystems have
occurred many times throughout the earth’s history, the average rate of warming
expected over the next 100 years, is likely to be greater than those that have occurred in
the past (Table 8.3). For many species the expected rate of change will be too rapid for
adaptation.

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25 Although soil water availability (dependent on rainfall and rate of evaporation) is the major determinant of primary
productivity in southern African terrestrial ecosystems, large uncertainties surround its quantification under an altered
climatic regime (Schultze et al 1993; Holme et al 1996).
26 With the exception of episodic (temporary) climatic changes e.g. the effects after major volcanic eruptions. Events
such as these can give us insight into the more gradual, less catastrophic changes we face now.
Table 8.3 A comparison of the rate of change in warming during different periods of the earth’s history (Pirie 1995)

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>Magnitude of change (°C)</th>
<th>Rate of Change (°C/decade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central England (medieval warm period)</td>
<td>1</td>
<td>5 X 10^-2</td>
</tr>
<tr>
<td>Ice Age interglacial (polar)</td>
<td>5 - 10</td>
<td>5 – 10 X 10^-2</td>
</tr>
<tr>
<td>Observed warming over last 100 years (global)</td>
<td>0.3 - 0.6</td>
<td>3 – 6 X 10^-2</td>
</tr>
<tr>
<td>Greenhouse predictions (global mean)</td>
<td>1.5 - 4.5</td>
<td>15 – 45 X 10^-2</td>
</tr>
</tbody>
</table>

Box 8.5. GLOBAL WARMING, DISRUPTED FOOD WEBS AND SPECIES LOSS
[Source: Hayden and Begley, 1997]

Average annual air temperatures and average winter temperatures on the Antarctic peninsula have increased by 2.8°C and 5°C respectively since the 1940s. Although the cause of this increase may be due only partly to human induced global warming, investigating its effects offers insight into how increased temperatures can disrupt food webs and cause changes in the species composition of ecosystems.

Warmer air over Antarctica holds more moisture and has resulted in more snow. Increased snowfall has reduced the number of suitable breeding sites of Adélie penguins, a species adapted to breeding on bare rocky outcrops, reducing their population by 40% since 1975. The noticeable decline in this species has been exacerbated by the fact that warmer temperatures have also resulted in less sea ice developing around the edges of the continent during the autumn months. The underside of sea ice provides an important habitat for single celled algae and the krill that devour it. Krill populations, which play a vital role in providing food for several marine species including penguins, have been reduced by between 60 – 90 % since the early 1980’s. Indigestible salps, adapted to the open ocean, are now rapidly replacing krill in the sea around the peninsula.

8.6.1 Impacts on terrestrial ecosystems

8.6.1.1 Biomal shifts and species loss

In response to elevated temperatures, the geographical ranges of terrestrial biomes in the southern hemisphere could shift 500-1000 km polewards (Lombard 1996). However, each type of plant has its own response to increased temperature and CO₂ (Box 7.5), its own growth, reproductive and dispersal/migration rate. As a result of these differential responses, competitive interactions between species are likely to change dramatically (Walker and Steffan 1997).

Thus, biomes will not migrate as intact entities and some species will be eliminated entirely. The rate at which existing ecosystems dissolve will exceed that at which new combinations of species and therefore, new ecosystems emerge (Walker and Steffen...
1997). In some areas in southern Africa, entire vegetation assemblages (e.g. the Cape fynbos) may disappear (Lombard 1995). Species most likely to be at risk include:

- Those currently at the edge of their optimal tolerance levels (temperature and nutrient requirements);
- Geographically localised species (those found on islands, inselbergs, mountain peaks, in remnant vegetation patches or in "island" parks and reserves);
- Genetically impoverished species;
- Poor dispersers; and
- Species that reproduce slowly.

The increased rate of species loss due to global warming will alter the trophic interactions within ecosystems, their net primary productivity and their nutrient, water and energy balance (IGBP 1996). At a national level, these disturbances to ecosystem functioning are capable of ultimately impacting on the economy of a country and its future development options. However, Figure 8.4 illustrates that more than just global warming needs to be considered when attempting to assess the future of the world’s natural and managed terrestrial ecosystems. Rather, the complex interactive effects of land conversion and changes in atmospheric composition, biodiversity and climate (collectively termed global change) must be taken into account (Walker and Steffen 1997). In addition, many complex feedback mechanisms occur between the causes and effects of global change on the biosphere. For example:

- Although increased atmospheric CO₂ may initially enhance the productivity and efficiency of water use in some plant species, excess greenhouse gas emissions are likely to result in the eventual loss of valuable vegetation sinks by 2080 – a result that will further increase future emissions and exacerbate their effects (Box 8.6).
- Overgrazing arid adapted perennial ground cover during prolonged periods of drought enhances land degradation (Box 7.7). Degraded land absorbs less CO₂, displays altered rates of evapotranspiration and is capable of impacting significantly on the atmosphere – changing ground and air temperatures, near surface wind speeds and turbulence, and ultimately affecting local and regional precipitation (Williams and Balling 1996).

8.6.1.2 Predicting local and regional changes in terrestrial biodiversity

The present generation of biogeographical models cannot adequately address the complex interactions between soil fertility, vegetation patterns and ecosystem processes that ultimately determine the biodiversity of an area (Hulme et al 1996). Furthermore, these models (eg. the BIOME model) are not well suited to climates that display a high degree of interannual variability. In spite of this, they can be used to indicate regions where

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27 Land conversion includes all land use changes and activities that result in alterations in land cover including overgrazing, the clearing of natural vegetation for crop cultivation, deforestation and the effects of fire. Incidence of fire is increasing in many parts of southern Africa (including Caprivi). Biomass burning involves significant interactions of the biological, chemical and physical processes that drive changes in the earth’s ecosystems and has potentially far-reaching implications for atmospheric and climate change (van Wilgen et al 1997).

28 This includes the effects of CFCs and other ozone depleting substances in addition to increased CO₂ and other GHGs.
Figure 8.4 The effects of global change on terrestrial ecosystem functioning
(Compiled using information from Walker and Steffan 1997; IGBP 1996)

- Elevated CO₂
- Increased temperatures;
- Altered rainfall patterns;
- Land conversion;
- Land degradation.

**CHANGES IN BIODIVERSITY AND ECOLOGICAL COMPLEXITY**
- Species loss;
- Bio-invasions;
- Altered habitats.

**ALTERED ECOLOGICAL FUNCTIONING**
- Primary Productivity;
- Decomposition and Nutrient Cycling;
- Population Dynamics.

- Changes in the spread of, and vulnerability to, pests, pathogens and vectors;
- Socio-economic impacts (e.g. loss of livelihood options and increased poverty);
- Diminished ability of managed ecosystems to provide food and fibre and natural ecosystems to provide essential services (e.g. clean water, removal of air pollutants).

* Ecological complexity refers to the diversity of trophic pathways and interactions within and between ecosystems (IGBP 1996).

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Box 8.6. INCREASED CO₂ AND THE LOSS OF VALUABLE SINKS
[Source: -:Anon.1997]

A study undertaken by Cannell et al., from the Institute of Terrestrial Ecology in Edinburgh indicates that, as emissions of CO₂ rise during the next 50 – 60 years, they will cause an overall increase in vegetation growth. The amount of CO₂ absorbed by the earth’s terrestrial vegetation is expected to rise from the present amount of approximately 2 billion tonnes/annum to approximately 2.6 billion tonnes/annum by the year 2050. However, the effects of global warming after 2050, particularly higher evaporation rates and lower rainfall, are expected to cause a collapse of tropical ecosystems, accompanied by a massive loss in biodiversity. Cannell’s study suggests that tropical forest will change to savanna or grassland and that present tropical grasslands will shrink from 8% to 1% of the global land area. As a result, the potential of the worlds vegetation to act as a CO₂ sink will decrease dramatically and, by approximately 2080, CO₂ uptake by terrestrial plants will be negative – with rotting vegetation emitting more CO₂ and other greenhouse gases than the remaining vegetation absorbs.
broad scale vegetation changes may occur and, on the basis of these outcomes, researchers are able to anticipate general responses of terrestrial species and natural and managed ecosystems at the local and regional level under certain climate change scenarios (Section 2.5.2.3). The following points, while offering a broad and incomplete picture, do provide some insight into what may occur during the next 50-100 years under an altered climate regime.

- Only those adapted to a wide range of conditions, which are capable of migrating and dispersing over long distances are likely to survive. However, although some plant and animal species may be able to migrate fast enough to keep up with projected climate change, they will only be able to do so if they are able to move through continuous (unfenced), relatively undisturbed natural ecosystems (Walker and Steffen 1997).

- As a general measure of the changes in biodiversity due to climate change, Hulme et al (1996) investigated the threat posed by possible biomas shifts to the ecosystems given some degree of protection in parks and reserves within the SADC region. Increased temperature alone will have an impact on between 17 and 19 per cent of the reserves in the region for all three climate change scenarios (Hulme’s ‘wet’, ‘dry’ and ‘core’ – Section 2.5.2.3). If water use efficiency (WUE) gains due to increased CO₂ are also accounted for (Box 7.5), impacts increase dramatically and between 25 and 38 per cent of the protected areas will be subjected to biomas shifts and accompanying biodiversity loss.

- The vulnerability of Namibian rangelands and possible responses of savanna ecosystems to the effects of climate change are considered in Section 7.4.1. Hulme’s ‘core’ and ‘dry’ scenarios suggest increased aridification (elevated temperatures and declining rainfall) in Namibia over the next 50 years. Under these scenarios annual grasses are likely to be favoured over perennials and increased rates of land degradation could occur - particularly in areas that are currently subjected to overgrazing during times of drought (Box 7.7). Semi-arid areas will become arid and dry sub-tropical areas could shift to semi-arid conditions.

- Fast growing, rapidly reproducing plants, with long range dispersal systems (typically weeds and bush encroachment species), are expected to benefit from global warming. These plants, which commonly yield less timber, provide lower quality foliage for domestic and wild animals and supply poorer quality habitats, are likely to outcompete long-lived and slow (or vegetative) reproducers (Pirie 1995; Lombard 1996; UNEP undated). Plants found in extreme deserts rarely display long-range dispersal mechanisms. Thus, even if Namibia’s desert areas were to become more moist, biomas shifts in vegetation may take a long time to respond (in WMO & UNEP 1995).
Based on increased temperatures and altered habitats, mountain zebra, springbok and other ungulate species could decline in Namibia’s arid highlands (Hulme et al 1996).

Disturbances to ecological systems due to changes in temperature, precipitation and weather will affect the range and activity of vectors, infective parasites and crop pests (Section 10.3.2.2). They will also alter the local ecology of water-borne and foodborne infective agents. As insects display rapid life cycles and high fecundity, they are likely to track changes in climate extremely effectively and increased bio-invasions of pests and disease carrying vectors are predicted for most areas in the world (UNEP undated).

An altered precipitation regime will affect runoff, river flow, water quality and availability. Riparian vegetation and their associated wildlife populations will be affected directly by these impacts, particularly as human demands for water are also increasing (Section 5.6.1). Permanent damage to the essential ecological processes (water purification, streamflow regulation and nutrient recycling) provided by Namibia’s natural wetlands is likely to occur.

The possibility of increasing aridity during the next 50 years is unlikely to threaten the survival of arid adapted desert and savanna desert plant and animal species that display innate resilience to Namibia’s dry, highly variable conditions29, unless they are already near their temperature tolerance limits. However some of these species will be vulnerable to other changes that could arise due to an altered climatic regime.

- Increased variability in the environmental conditions that drive the Benguela ecosystem due to global warming (Table 6.3 and Section 6.6.1.3) could result in fewer fog days and prolonged warm periods along the coast. This would threaten the survival of the many unique, endemic lichen, plant, insect, arachnid and lizard species, that are well adapted to survival on the Namib dunes, gravel plains and isolated rocky outcrops - mainly as a result of the moisture provided by coastal fog (Section 2.1.2).

- Increased temperatures, accompanied by reduced winter rainfall (Section 2.5.2.3) will threaten the species-rich rare succulent flora that characterise the desert areas in the Sperrgebiet.

8.6.2 Impacts on marine ecosystems

The expected effects of global warming on the marine fisheries sector and the general effects of sea-level rise on Namibia’s coastal zones and systems are considered in Chapters 6 and 9 respectively. These chapters should be cross-referenced with this section.

Substantial changes to the physical, biological and biogeochemical characteristics of the world’s oceans and coastal zones are expected to occur as a result of climate change. These changes in turn are likely to exert significant feedback effects on the global

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29 The Namib is often referred to as the oldest desert in the world. Evidence suggests that arid conditions have prevailed in western Namibia for 80 million years. The emergence of the Benguela current approximately 10 million years ago was accompanied by increased aridification and the development of the coastal fog belt (Ward and Corbett 1990).

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climatic system. However, the considerable lack of appropriate global studies on the functioning of marine ecosystems and the limitations of current GCM’s (Section 2.5.2.4 and Section 6.6), restrict the ability of researchers to predict, to any degree of certainty, the manifold, interactive effects of global change on marine ecological complexity. Nevertheless, some general suppositions can be made relating to the direct effects of enhanced concentrations of CO₂, sea-level rise (Section 9.2) and increased air and sea temperatures on Namibia’s coastal zones and marine organisms.

8.6.2.1 Predicting local and regional changes to marine biodiversity
In addition to the broad “what if” scenarios presented in Section 6.6, which contemplate the possible effects of climate change on the productivity of the Benguela system and the occurrence of anomolous events like Benguela Niños, the following possibilities regarding the effects of global warming on the structure and general ecology of Namibia’s coastal environment can be considered.

- **Potential impacts on the physical environment and habitats**
  - Elevated air temperatures and rates of evaporation could result in a compression of shore zones in a seaward direction, as sandy and rocky areas exposed during low tide are subject to increasing desiccation stress (in Lombard 1998).
  - Changes in tidal ranges are also possible, as wind and pressure regimes become affected by the weakening of the temperature gradient between the equator and the poles (ibid.).
  - An elevated sea-level will cause sandy beach erosion and sedimentation changes that are likely to threaten some coastal habitats. Rates of erosion, inundation and turbidity of inshore waters will increase with an increase in sea-level and are likely to affect the sediments of lagoons and other important coastal wetlands (Section 8.2.2 and Section 9.1). Namibia’s largest and most productive coastal wetland, the Walvis Bay lagoon, is possibly most at risk from the effects of sea-level rise as industrial and urban development have permanently altered its natural physical processes.
  - Namibia’s offshore islands, important roosting and breeding sites for several species of sea and shorebirds, are likely to be adversely affected by increased inundation and vulnerability to storm events as a consequence of sea-level rise (Section 9.3). Species that could be affected include African Penguin, Cape Gannet, Cape Cormorant, Bank Cormorant, Crowned Cormorant, Hartlaubs Gull and African Black Oystercatcher.

- **Potential impacts on coastal and marine ecology**
  - Increased SST (Section 2.5.2.4) is likely to be accompanied by increased temperatures throughout the entire coastal water column and the possible effects on both sandy beach and rocky shore species assemblages are numerous. Even a small increase in water temperature is likely to affect the growth, reproduction and metabolic processes of each type of organism and, as with terrestrial biota, each species will respond differently to the altered environmental conditions they are subjected to. Sedentary species which are restricted geographically by the
limiting effects of temperature (for example most seaweeds, which are both ecologically and economically valuable ‘keystone’ species) will be vulnerable to local extinction.

- Although many of the Benguela’s cold-adapted organisms may disappear from Namibian waters, the new, more tropical species assemblages that form are likely to display a higher degree of biodiversity (Section 6.6.1). In some temperate/cold areas of the world, a 2 °C rise in temperature could be accompanied by an increase in the number of species of up to 20% (De Vooy 1990). However, the higher species diversity that may develop is likely to be accompanied by lower production by the system as a whole, ultimately with severe economic implications for Namibia’s pelagic fishing industry.

- The distribution and population dynamics of the vast flocks of palaeartic and resident sea and shorebirds that frequent Namibia’s coastal zone are likely to be affected by alterations to their food supply. The geomorphological changes to sandy beaches, rocky shores and coastal wetlands mentioned above are likely to result in a reduction in the total abundance of intertidal organisms and mud-flat invertebrates available as prey. However, some improvements in shorebird food supply could also occur. The invertebrate species that survive the geomorphological changes might experience elevated rates of reproduction and growth and become more active (and therefore more accessible) particularly during the winter months due to elevated temperatures (Goss-Custard et al. 1990). However, it is not likely that these effects will be able to offset the negative impacts of sea-level rise and increased desiccation of the littoral zone on the feeding behaviour, population dynamics and ultimately, the biodiversity of many coastal birds (Goss-Custard et al. 1990).

- Cape fur seal pups are highly vulnerable to prolonged changes in the coastal wind regime (Section 6.3), and increased periods of higher air temperatures at the coast resulting from a slackening of the south-westerly winds or prolonged periods of hot east winds blowing from inland during the winter months would be detrimental to the local survival of this species. In addition, seals and all top predators of the Benguela system (fish, seabirds and cetaceans) will be affected by altered food supplies due to the changes in primary productivity that could accompany altered wind regimes, upwelling frequency and strength.

8.7 Conclusions

Natural ecosystems support processes that are essential for basic human survival. In addition, damaged natural habitats and losses in biodiversity due to human-induced factors ultimately reduce agricultural output, increase susceptibility to disease, lower standards of living and threaten Namibia’s future tourism industry and other development options.

It is not possible to prevent the loss of species and biomas shifts that are likely to accompany changes in global climate. However, by limiting damaging activities that either alter, fragment, isolate or stress Namibia’s natural ecosystems, the resilience of wild populations to future changes in atmospheric composition and climate will be enhanced. Consequently, all efforts to reduce the effects of global warming on
Namibia’s ecosystems must focus on conserving biodiversity and ecological complexity on a sustainable basis now. Cognisance must be taken of the complex interactive links that occur between the causes and effects of global warming, land degradation and biodiversity loss and concerted, multidisciplinary action to monitor, and ultimately mitigate, causes of global environmental change should become national priorities and be reflected in regional and international negotiations.

It is now recognised that unless the benefits of biodiversity conservation can be realised in monetary terms and directed towards those who currently bear the costs, the chances of preventing the continuation of environmentally damaging activities is extremely low. Most promising efforts in Namibia include the move towards developing profitable wildlife conservancies on communal and commercial farmland and the possibility of securing large, cross-boundary reserves within the region. However, much still needs to be done in order to ensure a sustainable future for Namibia’s invaluable wildlife populations and the water resources and habitats that support them, particularly in an environment that is beginning to display more extreme and variable climatic conditions.

**SOME RECOMMENDATIONS**

- Coastal and marine reserves must be proclaimed.
- In order to be viable as areas for species conservation, particularly under conditions of climate and other global change, terrestrial parks and reserves should:
  - be placed in areas of high biodiversity and/or high endemism[^30], include entire functioning ecosystems and be designed to span altitudinal, soil and climatic gradients – preferably on southern/northern limits of species ranges;
  - encompass movement and gene-flow corridors on both a local and regional scale.
- Support all efforts that help to ensure the management of natural ecosystems and resource harvesting (water, wildlife, wood, thatching grasses, fruits, herbs) on a sustainable basis.
- Improve the management of rangelands, fire and other causes of habitat destruction and land degradation.
- Create win-win incentives for sustainable development and appropriate ecosystem and natural resource management.
- Actively promote environmental education within all levels of society.
- Encourage research and monitoring of species that are sensitive indicators of marine and terrestrial environmental change.

[^30]: Extending the present protected area network to incorporate areas of high diversity and endemism, including the Kaokoveld escarpment, Spergebiet, Caprivi woodlands and river floodplains, the Otavi mountains, Brikkords and the coastal estuary at Sandwich Harbour (Barnard _et al_ 1998) will be a first step in this direction.
COASTAL ZONES AND SYSTEMS
COASTAL ZONES AND SYSTEMS

The Namibian coastline provides valuable migration and nursery habitats for many marine organisms. The few coastal towns and settlements are important centres for tourism, industry and commerce (Figure 9.1). This chapter focuses on sea-level rise and its potential impacts on Namibia's coastal zones and systems. The effects of rising sea surface temperatures, altered wind and pressure regimes and their expected effects on the marine fisheries sector and Namibia's coastal ecology are discussed in Sections 6.6 and 8.6.2 respectively. These sections should be cross-referenced with this chapter.

9.1 Brief overview of Namibia's coastal zones and systems

Namibia's entire 1600 km long coastal zone falls within the Namib Desert. Approximately 78% of the shoreline is comprised of sandy beaches, 4% of mixed shores of sand and rock and 16% of rocky shores. The surf zone is described as moderately high energy. Bays are scarce and lagoonal shores constitute only 2% of the entire coastal zone (Campbell 1993). The land that flanks the coastline comprises mobile sand dunes, extensive gravel plains and occasional exposed bed rock surfaces. Strong prevailing south-westerly winds transport sediment towards the shoreline and sand-drift towards the north-east. In certain areas lagoons and sand spits have formed as a result of the littoral drift of large volumes of sediment that enter the ocean via the episodic flooding of westward flowing rivers.¹

- Industries based on Namibia's living marine resources (fish, seals, rock lobster and mariculture) are reviewed in Section 6.3.
- Low rainfall and limited freshwater resources currently limit economic growth and the expansion of most coastal towns. The development of a desalination plant near Swakopmund by 2003 promises to ensure that future water demand at the coast will be met.
- Rapid urbanisation. Walvis Bay, Swakopmund, Lüderitz and Henties Bay have become major destinations for migrants from the northern communal areas in search of employment. It is estimated that these towns are currently growing at an average rate of 8-10% per annum² which contributes to growing unemployment, housing shortages and strain on health services (Ramboll 1995; CSIR 1997). Water and energy supply, sewerage systems and waste disposal facilities in these towns need to be upgraded if future demands are to be met. In 1995/96 unemployment in Walvis Bay and neighboring Swakopmund was estimated to be 10% and 30% respectively (UCT 1996). According to the 1991 population census, 61% of the population in Lüderitz were unemployed. The establishment of an EPZ in Walvis Bay, is expected to improve employment opportunities but is unlikely to solve the unemployment problem at the coast.
- The tourism sector has shown tremendous growth in recent years and continues to expand. Angling is one of the major attractions and the West Coast Recreation Area is renowned as an excellent area for sport fishing. The desert, sand dunes, Cape Cross seal

¹ For example, Walvis Bay.
² Between 1991 and 1995 Walvis Bay, Swakopmund and Henties Bay grew by an estimated 139%, 32% and 117% respectively (Ramboll, 1995).
Figure 9.1. Namibia’s Major Coastal Settlements and Sites of Ecological Importance

**LEGEND**

- Guano harvesting
- Mariculture
- Important wetland
- Tourism
- Harbour
- Town
- Seal colony
- Kudu Gas Field
- Diamond mining area
- Seaweed collection
- Salt harvesting

Area A: Skeleton Coast Park
Area B: West Coast Recreation Area
Area C: Proposed Walvis Bay Reserve
Area D: Namib-Naukluft Park
Area E: Diamond Area 1 (Sperrgebiet)

NB: Namibia’s 13 small offshore islands that provide safe breeding and roosting habitats for seabird colonies have not been depicted on this map. Nor have the small seasonal settlements of Witsukushaken (3 km north of Swakopmund) and the Langstrand-Dolphin Beach resorts (located between Walvis Bay and Swakopmund).

<table>
<thead>
<tr>
<th>TOWN</th>
<th>POPULATION (1995)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walvis Bay</td>
<td>55 000</td>
</tr>
<tr>
<td>Lüderitz</td>
<td>11 000</td>
</tr>
<tr>
<td>Swakopmund</td>
<td>23 300</td>
</tr>
<tr>
<td>Hentiesbay</td>
<td>3 500</td>
</tr>
<tr>
<td>Oranjemund</td>
<td>10 000</td>
</tr>
</tbody>
</table>

(Source: UCT, 1996; NAMDEB pers. comm.)

Möwe Bay is a small MET base camp and weather station (Pop. < 10). Terrace Bay is a small tourist camp with facilities for fishermen. Oranjemund is a town established by NAMDEB within the diamond concession area.
colony, German historical sites (particularly ghost mining towns near Lüderitz) and coastal birdlife also attract visitors to these areas. During the Christmas season the population of Swakopmund and Henties Bay more than doubles, placing additional strain on municipal services.

- **Mineral based industries.** Guano is harvested from four artificial bird platforms. In 1993 a total of 4202 metric tonnes was collected from these sites (Tarr 1996). Production fluctuates with bird populations and has declined considerably this century (Box 8.4). Namibia’s coastal conditions are highly suitable for the cheap production of salt through solar evaporation of seawater. Production from the three companies currently in operation is estimated to be 600 000 tons of 99.2 – 99.6% NaCl per annum. (Murray, 1993). Most of the salt is exported to African countries. Contamination by wind blown sand affects the quality of the salt produced in the Walvis Bay area and limits the expansion of this industry (UCT 1996).

Diamond mining is an extremely important revenue earner in Namibia. Activities in this sector are currently moving from onshore to offshore operations and the life of the known deposits is estimated at 25 years (until approximately 2025).

- **Aridity and poor soils limit the development of large scale agriculture along Namibia’s coast.** However, high quality asparagus, a saline resistant crop, is grown on small plots (20 ha in total) along the banks of the Swakop River. The value of this crop, most of which is exported to South Africa, is estimated to be approximately N$ 1.2 million per annum. (Rossing Foundation pers. comm). Small scale vegetable farming for the local market is practised along the banks of the Swakop and Omaruru Rivers.

- **Namibia’s coastal wetlands,** including the three Ramsar sites (Sandwich Harbour, the Walvis Bay lagoon and the Orange River mouth) provide valuable nursery areas for certain coastal fish species (H. Holtzhausen pers.comm) and feeding grounds for palaearctic and resident wading shorebirds. Industrial and urban development has reduced the flood area and altered the physical processes in the Walvis Bay lagoon, Namibia’s largest and most important wetland. This has affected the normal flushing of wind blown sand from this wetland resulting in increased siltation. Natural geomorphological changes threaten Sandwich Harbour. Pollution and industrial development threaten the Luderitz lagoon, salt marsh and tidal mud flats.

- **13 small off-shore islands** provide safe breeding and roosting habitats for several species of sea and shorebirds including African Penguins, Cape Gannet, Cape Cormorant, Bank Cormorant, Crowned Cormorant, Hartlaubs Gull and African Black Oystercatcher.

- **Pollution control** is inadequate throughout Namibia. Public awareness is low and littering has become a major problem in and around most urban centres. None of the coastal towns and settlements have separate disposal facilities for hazardous waste and municipal dumps are generally poorly designed and monitored (Tarr 1997). Neither the Walvis Bay nor the Luderitz Harbours provide adequate waste collection services, and it is common practice for ships to dump sewage and other waste in or near the harbour. The absence of bunker oil storage and processing facilities in these towns

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3 Regular bird counts conducted at the Walvis Bay lagoon since 1977 have shown that numbers of birds can reach up to 150 000 individuals (excluding Cape cormorants, Phalacrocorax capensis) during the summer months. (In Barnard 1998).
encourages oil spillage and dumping.\(^4\) Currently Namport is unable to cope with large oil spills. A national oil spill contingency plan does exist but is inadequate due to a lack of equipment and irregular rehearsal of procedures (Ramboll 1995). Increased traffic in both harbours is inevitable\(^5\) and increased pollution is expected. The presence of coastal fog and atmospheric inversions tend to concentrate any air pollution created at the coast and limits its dispersion. Air pollution which occurs in the environs of fish processing factories in Walvis Bay, is expected to increase as a result of the possible development of petro-chemical and other industries. Pollution of this nature will threaten the town’s prospects of developing a tourism industry.

### 9.2 Sea-level rise scenario

The IPCC concludes that “Even with substantial decreases in the emissions of major greenhouse gases, future increases in temperature and consequently sea-level, are unavoidable”.

Although it accepted with high confidence that global warming will cause sea-levels to rise, there remain many uncertainties relating to the actual assessment of the components that influence sea-level. These include the effects of changing volumes of polar ice caps, ocean thermal expansion and the dynamic effects that may result from altered ocean circulation, wind and weather patterns (WMO and UNEP 1995).

![Projected Sea-Level Rise using Scenario IS92a](source: UNEP, 1996)

\(^4\) Between 1993 and 1995, 27 minor oil spills and one major oil spill were recorded by Namport authorities.

\(^5\) The number of vessels calling at the port of Lüderitz increased by more than 300% between 1990 and 1995 and congestion of the harbour has begun to occur (CSIR, 1997). If production of gas from the discovery of the Kudu Gas field is found to be viable, traffic through the port is likely to increase even more dramatically.
It is estimated that global sea-level has risen by $1.0 - 2.5$ mm/year during the past 100 years and that this has been responsible for eroding 70% of the world's sandy coastlines (UNEP 1996). According to scenario IS92a, by 2030 global mean sea-level will be 6-25 cm higher than levels recorded in the mid-1990's. By 2070 the rise will be an estimated 10 - 65 cm and by 2100, 23 - 96 cm (Figure 9.2). Tide gauge records taken from Namibia (Lüderitz) and the west coast of South Africa (Port Nolloth and Simon's Bay) display increasing sea-levels over the past three decades. This rate of rise (roughly 27 mm per decade) is comparable with global estimates (Hughes et al. 1995).

9.3 The effects of sea-level rise
A range of coastal responses can be expected as a result of sea-level rise. These include the following biogeophysical effects (UNEP 1996):

- increased coastal erosion;
- flooding, inundation and displacement of wetlands and lowlands;
- impairment of water quality into freshwater aquifers and estuaries due to increased salt intrusion; and
- reduced protection from extreme storm and flood events.

However, it must be noted that the local and regional rate, magnitude and direction of sea-level change will vary considerably due to alterations in ocean conditions and vertical movements of the land. In addition, the actual response of coastal zones and systems to these changes will differ substantially according to local geomorphic conditions, sediment supply and ecology. Furthermore, the ability of coastal zones and resources to cope with natural climatic variability, changes in climate and sea-level rise decreases dramatically in areas that have been modified or exploited by humans (WMO & UNEP 1995).

Some important socio-economic sectors and sites of ecological importance in Namibia that could be impacted by increased sea-levels are listed in Table 9.2. Coastal impact assessments should provide detailed quantitative estimates for each of these impacts, but this requires site-specific knowledge of natural coastal systems and their socio-economic characteristics (Table 9.1).

Ideally, coastal zone impact studies will attempt to assess the expected damage costs of sea-level rise. In general, these can be divided into the following types:

- The capital costs of protective construction which can help to avoid land loss and a loss from increased flood frequencies;
- The recurrent annual costs of forgone land/wetland services;
- The costs associated with increased flood frequencies (Pearce et al. 1996).
Table 9.1. Data required to complete site-specific coastal impact assessments (Feenstra et al 1998)

<table>
<thead>
<tr>
<th>NATURAL COASTAL SYSTEM</th>
<th>SOCIO-ECONOMIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Coastal geomorphology/topography</td>
<td>• Demographic developments</td>
</tr>
<tr>
<td>• Relative sea-level changes&lt;sup&gt;6&lt;/sup&gt;</td>
<td>• Trends in resource use and economic</td>
</tr>
<tr>
<td>• Trends in sedimentation and erosion patterns</td>
<td>development</td>
</tr>
<tr>
<td>• Hydrological characteristics</td>
<td>• Land use and ownership</td>
</tr>
<tr>
<td>• Ecosystem characteristics</td>
<td>• Infrastructural and other economic assets</td>
</tr>
</tbody>
</table>
<pre><code>                                                             | • Cultural assets                         |
                                                             | • Institutional arrangements              |
</code></pre>

Table 9.2. Possible impacts of sea-level rise on some economic sectors and sites of ecological importance in Namibia (Author's compilation based on information from Feenstra et al 1998)

<table>
<thead>
<tr>
<th>IMPACTS on</th>
<th>Climate related impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coastal erosion</td>
</tr>
<tr>
<td>Water resources</td>
<td>✔</td>
</tr>
<tr>
<td>Agriculture&lt;sup&gt;7&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Salt mining</td>
<td>✔</td>
</tr>
<tr>
<td>Mariculture</td>
<td></td>
</tr>
<tr>
<td>Guano mining</td>
<td></td>
</tr>
<tr>
<td>Tourism and recreational angling</td>
<td></td>
</tr>
<tr>
<td>Human settlements</td>
<td></td>
</tr>
<tr>
<td>Infrastructure (port facilities and other)</td>
<td></td>
</tr>
<tr>
<td>Human health</td>
<td></td>
</tr>
<tr>
<td>Diamond mining</td>
<td></td>
</tr>
<tr>
<td>Financial services (insurance)</td>
<td></td>
</tr>
<tr>
<td>Wildlife habitats</td>
<td>Lagoons and River mouths</td>
</tr>
<tr>
<td></td>
<td>Offshore islands</td>
</tr>
</tbody>
</table>

<sup>6</sup> Vertical movements of the land need to be considered when assessing the impacts of sea-level rise. These land movements are regionally and locally variable and dependent on the natural geological conditions of an area and certain human activities, for example water and hydrocarbon extraction. Subsidence of the land will result in a relative sea-level rise that is greater than the global rise and uplifting of the land will result in a relative sea-level rise that is smaller than the global average (UNEP 1996). Exploitation of the Kudu gas field could result in a subsidence of the land.

<sup>7</sup> Asparagus cultivation is unlikely to be affected by an increase in soil salinity but the small scale vegetable farming practiced along the Swakop and Omaruru Rivers could be affected.
9.3.1 Vulnerability of Walvis Bay to the effects of sea-level rise

Walvis Bay is likely to experience impacts of first order magnitude to the effects of sea-level rise (Box 9.1). This low lying town (average relief of between 1m and 3m above mean sea-level) is located in a small, semi-sheltered bay (approximately 970 km²). The adjacent coastline is soft, sandy and erodible. The town currently relies on coastal aquifers, fed from sources underlying the Kuiseb and Omaruru Rivers, for water. Rainfall is usually in the region of 20mm per annum and storm water drainage is unnecessary. Consequently, no detailed topographical maps of the town are available.

Walvis Bay is of strategic economic importance to Namibia and land locked countries within SADC. It is the only deep water port on the Namibian coastline and handles delivery of most of the country's crude oil requirements and at least 40% by weight of Namibia’s total foreign trade (Hughes et al. 1992). Currently the port is underutilised with some 1.2 million tons of cargo being handled annually, compared to an estimated capacity of 4 to 10 million tons (UCT 1996). Recently improved road links between Namibia, Zambia, Zimbabwe and Botswana are expected to increase the flow of cargo through Walvis Bay and current plans are focused on expanding trade with the international world (Jurgens 1998). Walvis Bay is the centre for Namibia’s fishing industry and several fish processing factories, secondary industries pertaining to port maintenance and a salt mining company, represent the major commercial enterprises in the town. Tourism is increasing.

While the Walvis Bay town council is aware of the town’s vulnerability to rising sea-level, it is far more concerned about the possibility of flooding by the Kuiseb River. The dams upstream on the Kuiseb limit the flow of the river but will have no effect on a large flood event. The strongest floods in recorded history were experienced in 1934 and the river has not reached the sea since 1963. Since then, parts of the Walvis Bay lagoon (the rivers natural outlet to the sea) have been drained and converted into the luxury suburb of Meersig. This area can now carries a high insurance risk. In 1997 the best rains experienced for several years almost resulted in the Kuiseb River breaking through the dunes and flooding the lagoon area and its associated suburbs (Mr. Brummer pers. comm.). Recent palaeoflood evidence suggests that global warming in southern Africa is likely to be accompanied by more extreme floods (despite an overall decrease in runoff) (Zawada et al. 1998).

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*By the year 2003 Walvis Bay, Swakopmund and Henties Bay are expected to be receiving desalinated sea water and problems associated with overextraction, particularly from the Kuiseb aquifers, should be relieved.
* Topographical maps with 5m intervals are available but, for the purpose of quantifying those areas that may be affected by sea-level rise, more detailed maps (with 0.5m intervals) are necessary.
Box 9.1. **THE VULNERABILITY OF WALVIS BAY TO THE EFFECTS OF SEA-LEVEL RISE**

[Source: Hughes, et al 1992]

In 1991 a preliminary study was completed by the Oceanography Department at the University of Cape Town on the vulnerability of Walvis Bay to rising sea-levels. This study investigated possible impacts due to *increased erosion, flooding, elevated water tables and salt pollution and extreme storm events* for sea-levels elevated 20cm, 50cm and 100cm above 1991 levels. A résumé of the results from this study is given below.

- **Erosion**
  Application of the Brunn rule to 11 sites along the coastline within the environs of Walvis Bay indicate that the effect of increased coastal erosion is likely to have limited impact on the town. This is mainly because development has historically not occurred along the most dynamic and vulnerable parts of the coastline. Development in the most vulnerable built up area (adjacent to the lagoon) is no longer permitted.

- **Salt water intrusion**
  Continued unsustainable abstraction of water from the Kuiseb aquifer (at rates of >4000 m³/day) will result in salt water intrusion. Rising sea-levels will exacerbate this effect but the proposed development of a desalination plant near Walvis Bay and consequent reduced abstraction from the aquifer is likely to mitigate these effects.

- **Flooding and Inundation**
  Any rise in the water table from its 1991 position at about the MHWS level (0.71 m elevation) will have serious consequences for the town. Undoubtedly the tidal volume of the lagoon will increase but this is likely to be offset by the natural sedimentation of this wetland. A lack of accurate knowledge regarding rates of sedimentation in the lagoon precludes a realistic delineation of those areas that are at risk except to say that, under the three scenarios (a rise of 20cm, 50cm and 100cm), unprotected land below 0.9m, 1.2m and 1.7m elevation respectively, is vulnerable to inundation.

  Changes in saline groundwater levels under the town are likely to match changes in sea-level. Thus, those low lying areas vulnerable to inundation will be vulnerable to waterlogging even if shore protection work is carried out. In summary:
  - A 0.2m sea-level rise will cause areas lying below 0.9m, (e.g. the hospital and primary and secondary schools) to flood at high tide.
  - A 0.5m rise would flood a greater area of the town and harbour. This will affect production in the salt works and is likely to cause engineering and pollution problems in areas like the cemetery and sewerage works which all lie at approximately 1m above mean sea-level.
  - A 1.0m rise is likely to flood the majority of the town below 1.7m elevation during high tide.

- **Storminess**
  Under even the lowest sea-level rise scenario parts of Walvis Bay are expected to become extremely vulnerable to the effects of higher, storm induced coastal water levels. A future 1 in 10 year storm, after a 20cm rise in sea-level, would attain a higher water level than that which could be reached by a 1 in 1000 year event now.

**Recommendations**

The researchers suggested that a first step towards managing the above mentioned impacts of sea-level rise for Walvis Bay must include marking those areas most vulnerable to inundation, waterlogging and storm damage. A moderately detailed survey of the entire area is essential followed by a thorough plan of action for coastal defences or retreat. Furthermore all future development should take cognisance of the effects of rising sea-level.
9.4 Policy and Action

- The new Environmental Management Act, which incorporates pollution control, resource utilisation and land use planning, will help to ensure improved protection of Namibia’s coastal zones.
- The Walvis Bay municipality has developed a contingency plan in the event of the Kuiseb River flooding parts of the town (Mr. Brummer pers. comm.).
- The Walvis Bay municipality together with the public and private sector has initiated the Walvis Bay Lagoon Project which aims to reduce threats to the lagoon (development of roads, industries and housing). The municipality and the MET hope to proclaim most of the Walvis Bay enclave, including the popular sand dune area between Swakopmund and Walvis Bay, as a nature reserve.
- Integrated Coastal Zone Management (ICZM) provides a holistic means of incorporating environmental protection with developmental decision-making. ICZM is recognised as the most appropriate process to deal with current and long-term coastal degradation as it helps to reduce conflict of interests in resource utilisation and ensure co-ordination between stakeholders. A DANCED funded ICZMP for the Erongo Region, from the Ugab River mouth to Sandwich Harbour, was initiated in 1995. Key players include the MET and MRLGH with involvement from the MHSS, MFMR, MME, MLRR, MAWRD and MWTC. To date, this project has:
  - Drawn up a baseline report for an ICZMP in the Erongo Region;
  - Almost completed a coastal profile of the region - incorporating most of the data requirements mentioned in Table 9.2. Data collected has been transferred to a database and can be presented in a geographical information system (GIS) in order to enhance the understanding of all stakeholders regarding conflict of interests within the project area.

Although the effect of sea-level rise is not the prime focus of this ICZMP, information regarding the consequences of ENSO events, Benguela Niños and climate change is being incorporated into the coastal profile (J. Henschel pers. comm.). Furthermore, all information gathered by the ICZMP team will be useful in helping to formulate policies for development and will provide a valuable foundation for any future detailed vulnerability and adaptation studies at the coast.

9.5 Conclusions

One of the more certain consequences of climate change is a rise in global sea-level. This will compound the current stress placed on some of Namibia’s coastal zones, intensifying threats to ecological systems, human populations, infrastructure, and investment.

As each coastal site will display varying susceptibility and resilience to the effects of sea-level rise, it is essential to conduct impact assessment investigations, similar to the preliminary Walvis Bay study, on all of Namibia’s rapidly growing coastal settlements and sites of ecological importance. These include Oranjemund, the Orange River mouth, Lüderitz and associated wetlands, Swakopmund, Henties Bay, Cape Cross, the Kunene River mouth and the 13 small offshore islands which provide valuable breeding and
roosting sites for seabirds. The expected responses to sea-level rise then need to be incorporated as part of all other coastal zone planning, preferably thorough ICZMPs.

Some Recommendations

- Proclaim marine reserves.
- Ensure that no coastal development occurs in areas susceptible to sea-level rise.
- Incorporate the effects of sea-level rise in the design of new harbour/industrial facilities.
- Practice advance and integrated planning to avoid unnecessary impacts.
- Restore and protect all wetlands and other threatened coastal ecosystems.
- Support efforts to continue coastal biodiversity and ecological research particularly on indicators of environmental change.
- Develop and implement ICZMP’s for the entire Namib coast.
HEALTH
HEALTH

10.1 Current and future trends in national health

- Infant Mortality Rates (IMR), a measure of the number of babies under 1 year old that die, and childhood mortality rates for children under 5 years old, correlate well with the living conditions in a country and are often referred to as indicators of national health. Diarrhoea (42%), undernutrition (40%), malaria (32%) and acute respiratory infections (30%) are the cause of most deaths in the under 5 year old age group\(^1\) (MHSS personal communication 1998). The highest IMRs and under 5 year old deaths in Namibia occur amongst rural populations that are highly vulnerable to drought and were historically disadvantaged regarding access to adequate medical facilities, clean water and education (Figure 10.1). In 1990 the average IMR in Namibia was reported to be 65/1000 (UNICEF, 1990), but due to improvements in living conditions after Independence (Section 10.4) had dropped to 57/1000 by 1995.

Figure 10.1. Infant and Child Mortality per region [CSO, 1990]

- Table 10.1 highlights the disparity that still remains between urban and rural access to adequate services in the country. In spite of noticeable improvements since 1990, recent environmental health indicators for developing countries still rank Namibia as highly

\(^1\) Multiple causes of death often occur.
vulnerable to environmental impacts due to her water and food security status (WRI 1998). Circumstances in neighbouring Zambia and Angola are worse and cross border infiltration of communicable diseases poses a constant threat amongst communities where poor living conditions prevail.

- In 1996 AIDS, tuberculosis and malaria were identified as the main causes of all deaths reported in Namibia (Dr. S. Wessels, MHSS, pers. comm.) The exact effect of the HIV/AIDS epidemic is uncertain but it is accepted that over the next 10 – 15 years, it will cause an increase in mortality rates, a reduction in fertility and reduced population growth rates. In addition, the disease will place tremendous strain on Namibia’s future economy, partly through increased demands on social and health services (Box 3.1).

Table 10.1. Access to Basic Services in Namibia, Angola and Zambia (1990-1996) [WRI 1998]

<table>
<thead>
<tr>
<th>Percentage of population with access to:</th>
<th>Safe drinking water 1990-96</th>
<th>Adequate sanitation 1990-96</th>
<th>Health services 1990-1996</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban</td>
<td>Rural</td>
<td>Total</td>
</tr>
<tr>
<td>Namibia</td>
<td>87</td>
<td>42</td>
<td>57</td>
</tr>
<tr>
<td>Zambia</td>
<td>50</td>
<td>17</td>
<td>27</td>
</tr>
<tr>
<td>Angola</td>
<td>69</td>
<td>15</td>
<td>32</td>
</tr>
</tbody>
</table>

10.2. Drought and Health

In southern Africa El Niño events are strongly linked to current regional climatic variability and usually herald periods of severe drought. Under an altered climatic regime increasing climatic variability is expected for most of southern Africa, and for some diseases this may prove more important than changes in mean climate. Thus, investigating the effect drought has on disease offers some insight into how much impact an increasingly variable climate could have on national health.

- In rural areas, drought undermines a family’s ability to produce enough nutritious food and can advance the progress of land degradation (Box 7.7). Thus, frequent droughts can result in lowered resistance to disease and indirectly cause alterations in the distribution of certain vector species (Section 10.3.2.2).
- As the availability of sufficient, clean water diminishes during periods of drought the incidence of both waterborne (primarily diarrhoeal) and water washed diseases (e.g. scabies and conjunctivitis) are likely to increase in poor communities (Section 10.3.2.1).
- Vitamin A deficiency frequently becomes more common during drought conditions, affecting susceptibility to respiratory and gastrointestinal tract infections (McMichael et al 1996).

Namibia’s Vulnerability to Climate Change 10. HEALTH
10.3 Climate Change and Health

Murugasampillay, et al. (1996) report that diseases which have seasonal cycles and display interannual variations are most likely to be influenced by a changing climate. Multiple health impacts, including the unforeseeable emergence of new or resurgent diseases are likely to result from climate change but uncertainties regarding future climate scenarios and disease response make it difficult to predict the exact impacts that will be vested on any region (WRI 1998).

Figure 10.2  **Expected effects of climate induced impacts on health in Namibia** (Author’s compilation using information from WMO and UNEP 1995; McMichael et al 1996; IPCC 1997)

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Figure 10.2. offers a broad summary of the expected effects of climate change on human health in Namibia. Altered incidence of vector borne, water borne and water washed diseases and health problems relating to reduced nutritional status are most likely. However, increased incidence of toxic algal blooms (Boxes 6.1 and 10.2), heat related mortality\(^2\) and reduced resistance to disease as a result of threatened food security, disrupted water supply and increased pollen induced allergies and asthma can also be expected.

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\(^2\) Recent high temperatures have resulted in an increase in heat related mortalities around the globe. During 1997/1998 3,000 people died in India and 3,200 people were hospitalised in Cyprus as a result of abnormally high temperatures (Anon. 1998).
The effect of stratospheric ozone depletion is likely to cause an increase in skin cancers and possibly immune suppression in many organisms. However, incorporating these effects is beyond the scope of a health assessment for global warming.

10.3.1 Vulnerable Areas and Populations
Although a certain disease may be particularly sensitive to climatic change, the actual vulnerability of a population to that disease depends on many factors including:
- Patterns of human migration;
- Access to clean urban environments, nutritional food and potable water;
- Vector-control measures;
- Changes in resistance of vector organisms to control measures; and
- The availability of adequate health care (IPCC, 1997).

Thus, populations with high levels of natural, technical and social resources are less vulnerable to climate-induced health impacts (McMichael et al 1996). Table 10.2 offers a summary of the areas and populations in Namibia expected to be particularly vulnerable to the effects of climate induced health impacts.

<table>
<thead>
<tr>
<th>HEALTH PROBLEM</th>
<th>VULNERABLE POPULATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat related mortality</td>
<td>The elderly and infants in all areas</td>
</tr>
<tr>
<td>Altered distribution and prevalence of vector borne diseases</td>
<td>Communities that reside at the edge of endemic zones for these diseases e.g. the burgeoning informal urban areas developing around Rundu, Katima Mulilo, Ondangwa, Oshikati and Opuwo. All populations are vulnerable but particularly those living in overcrowded areas that suffer poor sanitation.</td>
</tr>
<tr>
<td>Water borne and water washed diseases</td>
<td>Particularly malnourished infants and children living in settlements with poor sanitation and water supply facilities.</td>
</tr>
<tr>
<td>Toxic algal blooms</td>
<td>Coastal areas. Particularly communities living in unsanitary conditions. Residents and tourists ingesting filter feeding molluscs are also at risk.</td>
</tr>
</tbody>
</table>

10.3.2 Climate Sensitive Diseases
10.3.2.1 Water Borne and Water Washed Diseases
The depletion and degradation of water resources plays an important role in determining levels of human health.

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3 Ozone depletion and its detrimental effects are the focus of the UN Convention for the Protection of the Ozone Layer and not the UNFCCC.
• Water borne diseases are transmitted when an aquatic pathogen is ingested with water and include: cholera; diarrhoeal conditions caused by salmonella, shigella, campylobacter, E.coli, rotavirus, amoebiasis and giardiasis; typhoid; Hepatitis A; pinworm, round worm and whipworm (Hardoy, et al. 1990). Many of these diseases are associated with unclean living conditions and are zoonotic (transmissible between humans and animals). Future epidemics of cholera due to environmental changes (including increased SST resulting from more frequent El Niño events and climate change) are expected globally (Box 10.1).

• Water washed diseases are caused by a lack of domestic and personal hygiene, often when there is insufficient water available to keep people and households clean. Amongst these diseases are included trachoma, scabies, dysentery and typhus.

Box 10.1. EL NIÑO, CLIMATE CHANGE AND INCREASED GLOBAL CHOLERA

Traditionally associated with war, natural disasters and unsanitary urban slums, cholera, a potentially fatal waterborne disease, has close links with the sea. The bacterial organism that causes cholera, Vibrio cholerae, thrives in moderately saline coastal estuaries and lagoons but can tolerate the open ocean. It will only inhabit freshwater systems if their organic content from pollutants such as human faeces is quite high.

The number of global cholera cases surged in 1991 causing a pandemic which swept from Asia through Latin America to Africa. Evidence suggests a close link between the sudden dramatic increase in the disease in 1991 and concurrent El Niño events. This evidence offers important implications for the future of the disease. El Niños are accompanied by warm water events that can encourage large plankton blooms, especially in coastal waters with high levels of nutrients from stormwater runoff and sewerage. These blooms are capable of “awakening” the cholera organism from the dormant state it adopts whilst in the ocean into an infectious state.

The frequency of plankton blooms that advance the spread of cholera in coastal urban areas is increasing worldwide. This is believed to be due to a combination of factors including higher ocean temperatures (linked to more prevalent El Niño events and global warming), increased nutrient runoff from expanding coastal populations and an additional plankton fertilising effect from increased atmospheric CO₂.

Cholera is unlikely to emerge in Namibia’s coastal desert towns, as none (with the exception of Oranjemund) lie on perennial river courses. However, in recent years, the disease has become increasingly prevalent throughout Angola - augmenting the chances of outbreaks in Namibian settlements near water courses in Caprivi, Kavango and the Cuvelai region.

10.3.2.2 Vector Borne Diseases

• Global change, including the combined effects of changes in land-use and climate, is likely to have an effect on the distribution of pathogens and their vectors in several ways:
  ◦ The geographic ranges of vector populations are likely to expand or contract as local and regional temperature, precipitation and wind patterns change.
  ◦ Changes in ecological complexity (Figure 8.4), such as the number of species in a community that regulate intermediate-host or vector populations, may enhance or decrease the spread of disease in human, domestic or wild plant and animal populations (Chapin and Sala 1996).
  ◦ Certain vectors, including some mosquito, tick and mite species, are dependent on local flora and their associated microclimate for shelter, feeding and breeding. Thus, human or climate induced changes to vegetation can result in changes in vector
distribution. In some cases, malaria has benefited from habitat changes, with *Anopheles* mosquitoes that prefer breeding in the open, establishing themselves in areas that have been deforested (McMichael et al. 1996).

- Besides altering the distribution patterns of vectors, climatic variables will affect vector biology in many other ways:
  - As their metabolic rate accelerates under conditions of increased **temperature**, blood-sucking vectors will need to feed more frequently. This, in turn, can lead to increased egg production and development (*ibid*).
  - Decreased **humidity**, as expected in many parts of southern Africa, could cause some vectors to feed more frequently to compensate for dehydration (*ibid*).
  - Although **precipitation** ultimately determines the absence or presence of breeding sites for vectors with aquatic larvae (mosquitoes and other biting flies), some species (e.g. *Aedes aegypti*) have become so well adapted to urban environments (breeding in discarded tin cans, flower vases etc.) that they remain relatively unaffected by precipitation (*ibid*).

Table 10.3 offers a summary of the more prevalent human vector borne diseases that occur in southern Africa. To date, attempts to assess the effects of global warming on regional shifts in distribution of the malaria and trypanosomiasis vectors have been made (Hulme et al. 1996).

**Malaria**

Countries in tropical Africa account for more than 90% of the total malaria incidence and the majority of malaria deaths. In southern Africa malaria is spreading due to the combined effects of population growth, drug resistance and global warming (Jury 1996a). Deforestation in many parts of Africa also plays a role in the spread of the disease. This is because *Anopheles gambiae* prefer breeding in the open and the rise in surface temperature that accompanies the clearing of forests speeds up the lifecycle of both the vector and the parasite it harbours (WRI 1998). Two of the most severe epidemics recorded since the 1930’s (and subsequent introduction of vector control) occurred within the southern African region in 1993 and 1996 (Dr. S. Wessels pers. comm.; le Sueur and Sharp 1996).

The major climatic factors, which either restrict or promote the increased transmission of malaria within a season, are temperature and rainfall. Rainfall impacts on the availability of suitable breeding sites and above average rainfall which begins early favours a longer malaria season and therefore increased incidence (le Sueur and Sharp 1996). Temperature impacts are displayed by the fact that the time taken for the vector egg to develop into an adult is on average, 5.5 times faster in summer than winter. Thus, slight increases in dewpoint temperatures due to global warming could significantly increase the potential area of malaria transmission in southern Africa during years of good rainfall (Jury 1996a).

In Namibia, about 60% of the population inhabit areas in which malaria is currently prevalent and the disease is estimated to be responsible for approximately 32% of childhood deaths after infancy (NPC 1997). Although the disease is reported all year round, the peak season occurs between January and May. Currently the incidence of malaria is
Table 10.3. *Some climate sensitive vector-borne diseases prevalent or potentially prevalent in Namibia* [Adapted from UNEP1996; WHO/CTD 1998; Hulme *et al.* 1996]

<table>
<thead>
<tr>
<th>Disease</th>
<th>Pathogen</th>
<th>Vectors/hosts</th>
<th>Presence in Namibia</th>
<th>Presence in Neighbouring Countries</th>
<th>Possible change in distribution due to climate change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td>Protozoan parasite Plasmodium <em>spp.</em></td>
<td>V: Mosquito <em>Anopheles gambiae.</em></td>
<td>✓</td>
<td>All</td>
<td>+++</td>
</tr>
<tr>
<td>Sleeping sickness (Trypanosomiasis)</td>
<td>Protozoan parasites Trypanosoma <em>spp.</em></td>
<td>V: Tsetse fly <em>Glossina</em> <em>spp.</em> R: Wild mammals (very seldom)</td>
<td>✓</td>
<td>Angola, Zambia</td>
<td>-</td>
</tr>
<tr>
<td>Lymphatic filariasis</td>
<td>Parasitic worm Wuchereria bancrofti</td>
<td>V: Mosquito mainly <em>Culex fatigans.</em></td>
<td>✗</td>
<td>Angola, Zambia, Zimbabwe</td>
<td>+</td>
</tr>
<tr>
<td>Yellow fever</td>
<td>Virus</td>
<td>V: Mosquito <em>Aedes aegypti</em> R: Wild Monkeys</td>
<td>✗</td>
<td>Parts of Angola and Zambia</td>
<td>+</td>
</tr>
<tr>
<td>Dengue</td>
<td>Arbor B group virus</td>
<td>V: Mosquito <em>Aedes aegypti</em></td>
<td>✗</td>
<td>Angola</td>
<td>+</td>
</tr>
<tr>
<td>Bilharzia (Schistosomiasis)</td>
<td>Parasitic worm Schistosoma <em>haemotobium</em></td>
<td>R: Aquatic snails</td>
<td>✓</td>
<td>All</td>
<td>++</td>
</tr>
</tbody>
</table>

*Malaria cont.*

considerably higher in the northern areas of the country (Figure 10.3) but changes in climate are expected to cause shifts in the distribution of the disease. All three of Hulme’s climate change scenarios (‘wet’, ‘dry’ and ‘core’, Section 2.5.2.3) suggest a net increase in habitat suitability for the disease vector *Anopheles gambiae*. The core scenario in particular suggests a spread in distribution into central Namibia (mainly the Omaheke and Khomas regions) (Figure 10.4).

Figure 10.3 indicates that a shift in the disease may already be occurring. Both the southern health directorate and central health directorate report a noticeable increase in incidents during 1997 when figures are compared with the epidemic malaria years of 1993 and 1996. Most incidents (84%) reported for the southern health directorate during 1997 came from the Gobabis district (S. Wessels pers. comm).
Figure 10.3. Reported malaria cases in Namibia per Health Directorate (Jan.-Apr. 1993-1997) [adapted from unpublished data, MHSS]
Figure 10.4. Potential changes in distribution of *Anopheles gambiae* in southern Africa under three climatic change scenarios [Source: Hulme, 1996]

Species: *Anopheles gambiae*

Probability of occurrence:
- ■ = 0.65 - 1.0
- □ = 0.55 - 0.649
- □ = 0.50 - 0.549
- □ = 0.45 - 0.499
- □ = 0.35 - 0.449
- □ = 0.25 - 0.349
- □ = Actual

Marks (S, p.2/3):
- Pmax
- Pmin
- Tmin
- P50
- Tmean
- Tmax
- Tmin
- Tmin
- Tmax
- P50
- Tmax
- Pmax

Training data results:
- Correct = 95
- False +ve = 2
- False -ve = 3
- Sensitivity = .955
- Specificity = .935

Comparison of the predicted distribution of *Anopheles gambiae* using the 1961-90 average data and the OSU 'Wet' scenario

Green = increase
Red = decrease

Namibia's Vulnerability to Climate Change  **10. HEALTH**
African Trypanosomiasis
Currently only a fraction of the estimated 55-60 million people exposed to the risk of becoming infected with trypanosomiasis have access to health centres where reliable diagnosis is available. Without treatment, the disease is usually fatal (WHO/CTD, 1998). The dominant climatic variables that affect the suitability of habitat for the disease vector, Glossina morsitans, appear to be temperature and evapotranspiration. T. congoense and T. vivax occur in eastern Caprivi. These strains affect livestock and not humans. However, this area of Namibia must be considered susceptible to the various strains of human sleeping sickness as incidence are currently reported from Angola and parts of Zambia (WHO/CTD 1998). Nevertheless, all three of Hulme’s climates change scenarios (‘wet, dry and core’ suggest a possible future reduction in habitat availability for G. morsitans throughout the southern African region.

Schistosomiasis
Global distribution of Schistosomiasis has altered significantly in the past 50 years. Control successes have been achieved mainly in Asia, the Americas and Middle East due to a combination of health education, provision of safe water, improved sanitation and snail control. However, water resources development, mainly through the building of dams, and increases in population densities have recently led to the spread of the disease to previously low or non-endemic areas - particularly in Africa (WHO/CTD 1998).

Schistosomiasis is a leading cause of severe morbidity amongst humans and cattle in southern Africa. In Namibia cases are reported from communities residing near to the perennial rivers in the north-east and north-west. The possible development of the Epupa Dam hydroscheme on the Kunene River could result in future increases in incidence of this disease in Namibia.

Lymphatic filariasis
This disease currently infects an estimated 120 million people globally and results in the unsightly swelling of body tissue known as elephantiasis (WHO/CTD 1998). Although not reported in Namibia, its presence in most of sub-Saharan tropical Africa including Angola, Zambia and Zimbabwe implies the possibility of invasion into the country’s northern communal areas under certain climate change scenarios. Poor communities, residing in unplanned urban settings, are most vulnerable to lymphatic filariasis (WHO/CTD 1998).

Dengue and Yellow Fever
During the last 20 years the incidence of dengue and dengue hemorrhagic fever have increased dramatically in tropical regions throughout the world mainly due to rapid, unplanned urbanisation (WRI 1998). The latter disease is responsible for 24,000 deaths annually (on average 5% of incidence in non epidemic years) (WHO/CTD 1998). There is no known treatment for yellow fever, an acute viral disease which kills up to 60% of those it attacks. Prevention is found in the form of a highly effective vaccine and it is
imperative that all travellers are immunised 10 days before entering areas where the disease is prevalent.

The vector for these diseases, *Aedes aegypti*, easily adapts to urban environments and, although encountered wild in most southern African countries, currently transmits the diseases only in Mozambique and neighbouring Angola. Climate change, improved transport within and between countries on the continent and the rapid growth of informal urban areas, suggest that outbreaks of dengue and yellow fever may begin to occur in previously unaffected areas, including northern Namibia.

### 10.4 Current Policy and Action

Mitigation of the effects of climate change on Namibia’s health sector depend largely on ensuring that the quality of life for both rural and marginilised urban communities continue to improve; reducing environmental damage; improving food security; improving disaster preparedness; and ensuring appropriate health care. An overview of the following policies and programmes offers some insight into how well Namibia’s future society will be able to cope with climate-induced health impacts.

**Quality of life**
- Since independence the MHSS has shifted resources to previously disadvantaged regions, focussing on preventative care and the provision of clinics within rural communities. Improved primary health care programmes and access to health facilities have resulted in increasing immunisation rates and a drop in the number of under 5 year old deaths (Section 10.1). Continual improvements in water supply, particularly to the previously neglected northern communal areas will help to ensure improved human health in Namibia.
- Many of the rapidly developing urban areas in Namibia remain neglected with respect to the provision of adequate housing, waste and sewerage management.

**Environmental damage and food security**
- See Sections 7.3.2 and 8.5.

**Disaster preparedness**
- In 1993 the Epidemiology and Public Health Division (EPHD) of the Ministry of Health and Social Services (MHSS) began collecting data on the incidence of malaria in Namibia. The EPHD are actively involved with the Malaria Forecasting Project which falls under the auspices of the University of Natal Medical School and the Malthat Research Institute (Liverpool School of Tropical Medicine). This project focuses on the development of reliable statistical models for predicting late summer rainfall in southern African countries and direct malaria incidence per capita (Dr. S. Wessels pers. comm.; Jury 1996a).

The MARA project set up by South Africa’s Medical Research Council uses GIS gathered and mapped information to determine the geographical occurrence of malaria, the environmental determinants relating to its transmission in any one season, its transmission intensity and frequency of occurrence across the African continent. Models are used to extrapolate results for areas where no information currently exists.
(Stadler 1998). Projects such as these offer the potential for long range forecasts of malaria incidence. This will help the medical community within the region to combat the growing threat posed by this disease and prepare for the outbreak of seasonal epidemics.

- See Section 7.3.2.

10.5 Conclusions
The health of human populations is closely linked to the integrity of the Earth’s natural ecosystems. Therefore, the disruption by climate change to food and water supply, weather patterns, and ecological complexity is capable of creating abundant health risks. Vulnerability to these risks increases dramatically in areas that have been disturbed by human activities and amongst communities that are overcrowded, suffer from poor nutrition and receive inadequate water and sanitation.

In recent years, commendable efforts have been made to improve the basic living conditions of the majority of Namibia’s rural population. However, many of the country’s burgeoning informal urban communities, in the absence of adequate services, are becoming increasingly susceptible to disease and the potential risks posed by an altered climatic regime.

Determining the effect of Namibia’s natural climatic variability on human health can play an important role in assessing climate change impacts on disease and in the development of disaster preparedness strategies. Normal climatic variability and the frequency and severity of drought episodes in southern Africa are amplified during El Niño events. Therefore, an assessment of the impacts of ENSO (both the wet and dry phases) on national health will provide a useful tool for future studies on the effects of increased climatic variability due to global warming.

There remains a need to investigate the possible spread into Namibia of many diseases currently prevalent in neighbouring countries. The effect of global warming on the habitat suitability of *Aedes aegypti* and *Culex fatigans*, in particular, should form the focus of future in depth studies within this sector.

Some Recommendations
- Continue to improve water quality and ensure food security for all Namibians.
- Continue to improve and extend medical care services and vaccination programs to Namibia’s most marginalised populations.
- Conduct education campaigns to improve public knowledge of water and vector borne disease.
- Improve housing infrastructure, sanitation services and waste removal in informal urban areas.
- Plant trees to reduce urban heat island effect.
- Increase health surveillance integrated with environmental and climatic modeling.
- Improve disaster preparedness and ENSO forecasting.
- Encourage regional studies on the possible effects of global warming on the distribution of yellow fever, dengue and lymphatic filariasis.
11.2 Current energy sources and supply
All petroleum and coal products and a considerable proportion of Namibia's electricity are imported.
- The parastatal company, NAMPOWER, controls supply of bulk electricity. Supply of electricity within the country's borders comes from the following sources:
  - The Van Eck coal power station (Windhoek) which has an installed capacity of 120 MW. Between 1989 and 1992 this station supplied less than 5% of the total electricity generated in Namibia and since 1990 has operated at only 10% of its capacity because of the increasing price of coal imported from South Africa. (NEPRU, 1993).
  - The Paratus power station (Walvis Bay) which has a capacity of 46 MW and can operate of diesel or gas. Its main function is to supply Walvis Bay with electricity in the advent of problems experienced with the national electricity grid.
  - The Ruacana hydroelectric power station situated below the the Ruacana Falls on the Kunene River has a capacity of 240MW and produces most of Namibia's locally generated electricity. During periods of good rain, Ruacana has produced excess energy which has been exported to South Africa. However, in most years Namibia needs to import about half of its electricity from South Africa and Zambia\(^2\). Damage to the Gove Dam sluice gates in Angola is currently limiting flow to the Ruacana station and any future development projects upstream threaten the long term viability of this source of energy.

11.3 Major challenges
The broad challenges that currently face Namibia’s energy sector include:
- The need to improve access of historically disadvantaged rural communities to commercial energy resources; and

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\(^2\) The amount of imported electricity fluctuates from one year to the next depending on precipitation in the catchment area of the Kunene (in the Angolan highlands) and river flow. In 1991/92 and in 1996, Namibia imported 47% and 60% of its electricity respectively. A figure of 85MW is indicated by NAMPOWER as the lowest average capacity of Ruacana during times of drought. (NEPRU 1993).
11.4 Future demand and supply
Before attempting to review the likely effects of global warming on Namibia's energy sector it is necessary to determine an expected baseline scenario for future energy demand and supply irrespective of climate change.

11.4.1 Future demand
Annual growth in energy demand is predicted to increase considerably due to the rapidly expanding population and high rates of urbanisation. If strategies for economic growth and improved welfare are successful, standards of living will increase and further increases in energy demand can be expected. Planned water transfer schemes, particularly those involving pumping and/or desalination (Section 5.5.2), will dramatically increase the demand for energy from the water sector. However, these increases will be partially offset by low growth forecasted for the mining sector and national energy demand at a growth rate of approximately 3% until 2005 (Table 11.1).


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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Demand (MW)</td>
<td>241</td>
<td>248</td>
<td>256</td>
<td>263</td>
<td>271</td>
<td>279</td>
<td>288</td>
<td>296</td>
<td>305</td>
<td>314</td>
<td>423</td>
</tr>
<tr>
<td>Annual Growth %</td>
<td>3.0</td>
<td>2.9</td>
<td>3.2</td>
<td>2.7</td>
<td>3.0</td>
<td>3.7</td>
<td>3.2</td>
<td>2.8</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

11.4.2 Future supply
Wood
The increasing problem of bush encroachment (Chapter 7) in parts of Namibia has created excess wood in these areas. Some of this wood is currently used in charcoal production but the potential for these areas to be cleared in order to supply fuel to communities that have fuel shortages has been recognised (MME 1998). The feasibility of moving wood resources from one part of the country to another still requires investigation.

Electricity
Electricity importation and distribution over long distances to Namibia's relatively small energy market is expensive and will place growing demands on the country's foreign exchange. Connecting rural areas to the grid is estimated to cost an exorbitant N$ 30 000 per km (Müller 1995)⁴. As the majority of rural households have a low purchasing power relative to commercial energy costs, imported energy is not considered to be

³ Refer to national GHG mitigation report for more recent statistics
⁴ This cost is given at 1994 prices and is for the grid alone. It does not include the establishment of other supply structures to the rural areas.
economically viable for these areas. Thus, dependency on batteries, paraffin and diminishing supplies of wood by Namibia’s poor rural majority is unlikely to abate during future decades unless other energy sources can be supplied cost effectively.

- In order to make Namibia self sufficient in electricity production :-
  - The MME proposes building a large hydroelectric dam on the Kunene River. An EIA has been conducted to investigate the environmental and social costs of building this dam.
  - The Kudu gas field, located approximately 170km offshore from the Orange River mouth, will be developed. This valuable new source of energy is expected to be functional for approximately 20 years from the year 2002. However, its establishment will incur huge capital costs of approximately N$ 2 billion and the possible risk of marine pollution (Ashley, et al. 1995).

Although both of these options offer an opportunity for Namibia to achieve self-sufficiency in electricity production, neither will be able to meet the growing demands of remote, dispersed populations in the rural areas without further substantial expenditure.

Alternative sources
The potential for energy conservation and the use of environmentally friendly solar and wind energy in Namibia is currently being investigated by the MME. Solar energy, in particular, has tremendous potential for meeting energy demand cost effectively in rural areas and mitigating GHG emissions (Box 11.1).

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**Box 11.1. SOLAR POWER FOR THE PEOPLE – A COST EFFECTIVE OPTION?**
[Sources: Ashley et al, 1995; MME 1998]

_Solar radiation in Namibia is higher than in any other country in the world (between 2000-2360 kWh/m²/year) and the potential for developing solar power is enormous._

Approximately 20 000 rural households are not yet connected to the grid in Namibia and most of their energy needs are currently met through the unsubsidised use of dry cell batteries, paraffin and the extensive use of firewood. Although the purchase of a small photo-voltaic unit generating 100 kilowatt-hours per year would appear to be a far more expensive option for the average household being connected to the (subsidised ) grid, a solar investment on the national level would be a clean, relatively cost effective option.

The estimated cost of developing the Epupa hydro-power scheme is N$1.5 billion. Burning coal to provide equivalent rural electricity would cost an economical N$ 1-2 million a year for coal imports but would emit 10 000 tonnes of CO₂ a year. Over and above these two options, the current grid would need to be extended to the rural areas - costing an additional, estimated N$350 million. The use of paraffin and batteries, although economical, carries heavy environmental costs which include the emission of 30 000 tonnes of CO₂ a year and the uncontrolled dumping of 5.6 million batteries.

The capital cost of supplying 200 000 households with photo-voltaic units would be N$740 million or half of the capital cost for the Epupa scheme. If solar water heaters are used to substitute the estimated 40 000 electrical geysers in urban centres, annual electricity consumption would be reduced by 48 000MWh/year, saving the equivalent of N$7 million in coal imports and an estimated 45 000 tonnes of CO₂ emissions.

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3 90% of Namibia’s 200 000 households not connected to the grid purchase an average of 90 litres of paraffin a year and 70% use about 40 dry cell batteries a year.
4 All prices are for 1994.

_Namibia’s Vulnerability to Climate Change. II. ENERGY_
11.5 Potential vulnerability of the energy sector to climate change

Climate change is likely to affect both energy production and consumption in Namibia. Any policies and actions that are adopted specifically for the amelioration of GHG emissions are likely to have a significant effect on the energy sector and future economy of the country, however a reviewal of these possibilities falls beyond the scope of this document.

11.5.1 Climate change effects on energy production

Hydroelectric generation
Drought and low flow regimes of the Kunene River already affect hydropower output in Namibia (Section 11.2) and, with the possibility of increased frequency or magnitude of drought events in the region, this impact could become progressively worse. Reduction in river flow during years of low rainfall is likely to be compounded by increased demands from upstream users for irrigation and domestic water schemes.
Some climate change scenarios suggest an increase in precipitation in the tropical regions of southern Africa (Tyson 1991). Thus, although Namibia may become drier, the catchment areas of the Kunene River (in the Angolan highlands) could receive more rain. This scenario would enhance future hydropower output from the proposed Epupa dam.

Thermal electric generation
The overall effect of global warming on thermal electrical generation power (using coal and/or Kudu gas) will be small although higher temperatures could decrease the efficiency and capacity ratings of natural gas or oil fired combustion turbines.

Wood
Although by no means conclusive, climate change may favour the spread of bush encroachment species in vulnerable areas within the country (Section 8.6.1.2). Total fuel wood supply may therefore be enhanced by global warming, but will still require transportation to the remote areas where it is most needed.

Solar and wind power
Changes in the number of sunny days per year or changes in wind patterns resulting from climate change will alter the viability of solar or wind generated power within an area. Current climate change scenarios that suggest a hotter and drier future for most of Namibia imply that solar generated power will not be threatened by global warming. If hydropower generation becomes severely hampered due to prolonged periods of drought, the use of solar power (Box 11.1) could gradually become an economic necessity.

Other
Energy production facilities near or in the ocean (e.g. Kudu gas) could be subject to damage from the effects of sea-level rise (Chapter 9). Increasing intensity of extreme weather conditions (e.g. strong winds) could increase damage to electric transmission lines and solar generating stations.
11.5.2 Climate change and energy demand

Higher temperatures resulting from global warming could cause a substantial increase in electricity consumption, mainly as a result of increased use of air conditioners and other cooling equipment. In Namibia the magnitude of this impact will depend largely on future economic development, as an improved standard of living will result in the use of more electricity and consequently more cooling systems.

11.6 Conclusions

Most developments within the energy sector are capital intensive and require long term planning. Therefore, unless the potential effects of global warming are seriously considered during current planning processes, Namibia could face large financial losses as a result of climate-induced impacts to both the consumption and production of energy in the future. The extent of these effects is closely linked to economic development and will largely be determined by the country’s future dependency on woodfuel and electricity produced from hydropower.

In order to assess the full extent of the future vulnerability of Namibia’s energy sector, specialist studies will require:

- A thorough assessment of current and projected future water use in Namibia, particularly during periods of drought, in conjunction with creating estimates of how the flow of the Kunene river is expected to change in response to altered precipitation and evapotranspiration conditions. Increased demands from Angolan users need to be considered too.
- The development of a complete inventory of current and future biomass utilisation patterns for energy supply and other uses. Estimates of future biomass availability under climate change scenarios then need to be developed and compared with projected future demand.

Some Recommendations

- Diversify into alternative energy sources and encourage flexibility in the energy sector. This will enhance resilience and adaptability in the face of changing environmental conditions.
- Conduct education campaigns regarding water and energy conservation;
- Move away from water intensive industries;
- Reduce water and energy demand;
- Conserve riparian vegetation and improve water and soil management to increase infiltration to groundwater and stabilise river flow;
- Encourage reforestation and improve the management and productivity of existing biomass resources.
- To avoid heat island effect and the increasing use of air-conditioners, town planners should strive to include greenspaces within cities and towns.

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7 In the USA, it has been estimated that a 3.7°C warming by 2055 would result in a net increase in electricity demand of 20% above baseline, requiring additional annual operating costs of US$ 53 billion (WMO and UNEP, 1996).

Namibia’s Vulnerability to Climate Change. 11. ENERGY
FINAL CONCLUSIONS AND RECOMMENDATIONS
FINAL CONCLUSIONS AND RECOMMENDATIONS

Namibia is extremely sensitive to global warming and, due to institutional and financial constraints, is considered highly vulnerable to the effects of climate change. The direct impacts of global warming on each of the economic sectors reviewed in this document have the potential to create ripple effects on each other, ultimately reducing productivity, sustainable development options and social stability. If, as currently suggested by some regional scenarios, the country’s climate continues to become hotter, drier and more variable (with the exception of Caprivi, where it may become wetter), it is clear that marginalised rural and urban populations will suffer the most.

Although many country studies concentrate on the isolated sectors that will be affected by climate change, an integrated approach which takes cognisance of the many between-sector interactions of the different climate driven impacts, will result in a far more comprehensive analysis of the ultimate effects of global warming. Future vulnerability and adaptation studies in Namibia are therefore urged to take the latter approach, as it will enable researchers to consider the impact of an altered climatic regime on broad, interdependent issues relating to the sustainability of our future - such as land-use, resource management, food security and economic development.

Significant links and overlaps occur between the effects of climate change, biodiversity loss, ozone depletion and desertification. Thus, national and international action must be integrated and co-ordinated to avoid the duplication of programmes and activities.

Bearing in mind these considerations, the working group on Vulnerability to Climate Change from the Final Workshop for Namibia’s Initial Climate Change Report held in Windhoek (February 10th 1999) recommended the following:

1. Research
   - The creation of plausible baseline scenarios necessary for future sectoral vulnerability studies will be able to draw on information from the Natural Resource Accounting Programme, the National Biodiversity Programme, Namibia’s State of Environment Reports, NetWise and other ongoing projects. Nevertheless there is a strong need for the development of human resources and the continual creation of reliable databases on climate, soils, vegetation and fauna. All efforts to develop such databases and networks must continue.

   - Ongoing climate modelling, specific to Namibia, is essential for all forthcoming research. There is an urgent need to build up capacity, systems of information exchange and co-operative research within the region regarding this highly specialised aspect of vulnerability and adaptation studies.

   - Quantifying the potential socio-economic and biophysical impacts of climate change on Namibia’s water resources should form the focus of immediate research. It is recommended that all other research should focus on those impacts that are expected to have specific effects on human livelihoods and well being, and are unlikely to be pursued by the National Programme to Combat Desertification (NAPCOD), the National Biodiversity Task Force or marine resources research that aims to improve
understanding of the effects of the natural environment on fish population dynamics. Some suggestions include:

- Investigating the direct effects of climate change on food security amongst rural communities. Focus should be on sorghum, millet, etanga (*Citrullus lanatus*), and omakunde (*Vigna unguiculata*) growth, important fruiting and tuberous veldkos species, the potential for increases in crop pests, pathogens and livestock disease, and the adaptation options regarding these impacts.
- Investigating the effects of climate change and the possible adaptation measures that can be taken on the health of marginalised urban and rural populations in northern Namibia – an area that could become increasingly susceptible to vector borne diseases and other pathogenic invasions from neighbouring states.

2. **Adaptation and Disaster Preparedness**

More extreme weather events (both droughts and floods) are likely to characterise Namibia’s future climate and it is important to identify cost-effective adaptive management approaches. National preparedness regarding extreme events and the secondary impacts that accompany them (including the threat of bio-invasions, disease epidemics, reduced food security and increased rates of human migration) is required. These national disaster response strategies should become an integral part of Namibia’s sustainable development planning.

Development planning, particularly at the strategic and project levels must take cognisance of the potential impacts of climate change. For example, the allocation of land for specific land-use must consider the potential effects of increasing climatic variability. Similarly, risk assessments within project EA’s must consider the possibility of increased frequency of large flood events.

3. **Creating Awareness**

In addition to informing policymakers about the possible effects of climate change, decision-makers at all levels including government officials, local and traditional authorities, farmers and the general public should be kept informed about Namibia’s interseasonal and interannual climatic variability. Publications similar to the monthly *WHO?* Bulletin produced by Namibia’s Meteorological Services are a good example of how relevant climatic information, and the implications thereof, can be provided to all stake-holders.
Caprivi fights off army worm, locust ‘invasion’

Drought looms in Kunene area

Many San face food shortages

Tourism must be treated as ‘priority’ economic activity

Dam levels down

Poor land use hitting water resources

Headlines in The Namibian February 1998
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APPENDICES
Appendix 1  Climate Change Scenarios for Namibia

In this appendix, climate change scenarios, based on Global Circulation Models (GCM) are used. Because of the known uncertainties of these models over long time spans, and because of the uncertainties over the future trends in greenhouse gas production, their results fall short of being thought of as actual predictions, and rather are called ‘scenarios’. These scenarios are thought to give the right order of magnitude for the climate change, but are less certain as to the time scales involved. This appendix provides no more than a preliminary assessment of possible scenarios. It is still important that a more detailed assessment is made in the future.

We use two standard approaches in this report. Firstly, that of the U.S. Country Studies Program uses GCM’s to estimate the effect on the climate of doubling the CO$_2$ content of the atmosphere (2XCO$_2$). Results from several models are available to do this. The procedure is to test the models for Namibia using existing CO$_2$ levels (1XCO$_2$), select those models whose results best match the existing climate, then use these models to produce scenarios by doubling the CO$_2$ input into the models. In these cases, no time scale is involved, which provides some flexibility in matching the model outputs to existing and future changes in CO$_2$ production. Secondly, transient models are used. These attempt to use a prediction of the production of CO$_2$ and other gases on a year by year basis, using these predictions as inputs into the model on a temporal basis, and thus obtain scenarios for specific dates in the future. In particular, the IPCC reference scenario (the IS92a Emissions Scenario, see box) involves predicted population, economic activity, energy use, technical advances and agricultural changes to estimate future CO$_2$, methane, nitrous oxide, halocarbons, CFC’s and HCFC’s emissions, which are then incorporated as part of the input to the GCM’s. The outputs from these models are related to dates in the future.

The models used in the first step are:-

1XCO$_2$, 2XCO$_2$
GFD3, Geophysical Fluid Dynamics Laboratory Model 3.
GISS, Goddard Institute for Space Sciences
CCCM, Canadian Climate Centre
UK89, United Kingdom Meteorological Office, 1989 run

Transient
GF01, Geophysical Fluid Dynamics Laboratory, runs at 40, 70 and 100 years.
UKTR, the UK Meteorological Office transient model.
CCC, the Canadian Climate Centre transient model.
OSU, the Oregon State University transient model.

Five stations were used in this preliminary analysis, Windhoek, Ondangwa, Grootfontein, Keetmanshoop and Pelican Point (Walvis Bay).

The first five model results were obtained from a programme GCMS provided by the CEEST team, and the last three from the SCENGEN package, provided from the University of East Anglia, UK.
The IS92a Emissions Scenario *

The IPCC’s “reference” or “a” scenario (Leggett et al., 1992) relies on population projections published by the World Bank in 1989. World population is projected to approximately double to 10 billion in 2050, after which growth slows to a total of 11.3 billion in 2100. The economic growth rate assumptions were devised by the IPCC and fall at the low end of the ranges forecast by the World Bank in 1991. Economic growth rates decline after 2025. The amount of energy consumed per unit of output—the energy intensity—declines in OECD countries and China, but remains about the same in developing countries through 2025. After 2025, energy intensity decreases more sharply in developing counties than in the OECD countries. The scenario also assumes that the price of solar energy will drop and the price of nuclear energy increase until they are at about the same level. Reliance on natural gas and petroleum is assumed to increase steadily until 2025 and then decline until consumption falls below 1990 levels by 2100. Consumption of coal, however, is assumed to increase throughout the twenty-first century until consumption is seven times current levels by 2100. In the scenario, net CO2 emissions from deforestation remain roughly at 1 Gt per year, but then decline after 2025 as diminishing land clearing results in net storage of −0.1 Gt per year by 2100. Methane emissions from livestock are projected to double by 2025, but all of the increase in emissions from enteric fermentation is expected to come from developing countries. Emissions from rice cultivation increase more modestly as gains in productivity are assumed to be greater. These sector-specific assumptions translate to roughly a doubling of anthropogenic methane and nitrous oxide emissions by 2100 and a tripling of anthropogenic CO2 emissions by 2100. The projections of halocarbon emissions were revised by the IPCC in 1995 (IPCC, 1996a), compared to the original IS92a scenario, to account for the more rapid phase out of CFC’s and HCFC’s required under the Copenhagen amendment to the Montreal Protocol on ozone-depleting substances.

* copied from Hulme, 1996

TEMPERATURES

Doubling CO2

For the 2XCO2 models, the square root of the mean of the square (RMS) deviations for the model monthly temperatures from the climatological monthly mean temperatures was used as the test criterion for the suitability of the model for Namibia. The results for temperatures were:

<table>
<thead>
<tr>
<th>Station</th>
<th>GFD3</th>
<th>CCCM</th>
<th>GISS</th>
<th>UK89</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windhoek</td>
<td>1.19</td>
<td>1.55</td>
<td>1.77</td>
<td>2.46</td>
</tr>
<tr>
<td>Ondangwa</td>
<td>2.62</td>
<td>1.41</td>
<td>1.92</td>
<td>0.83</td>
</tr>
<tr>
<td>Grootfontein</td>
<td>0.77</td>
<td>1.90</td>
<td>1.61</td>
<td>1.54</td>
</tr>
<tr>
<td>Keetmanshoop</td>
<td>4.53</td>
<td>3.41</td>
<td>2.21</td>
<td>4.97</td>
</tr>
<tr>
<td>Pelican Point</td>
<td>3.58</td>
<td>40.8</td>
<td>4.91</td>
<td>1.35</td>
</tr>
<tr>
<td>Mean</td>
<td>2.54</td>
<td>2.42</td>
<td>2.48</td>
<td>2.19</td>
</tr>
</tbody>
</table>

Table 1. Root Mean Square Deviations of Model Outputs from Climate (Actual) Values.

Overall, the UK89 model performed best, though only because it performed well for Pelican point. It was the worst for two stations. The other three models were very
similar in terms of modeling existing climate. Therefore it seems logical to utilise all four of these models for the 2XCO2 scenario.

For illustrative purposes, the model comparisons for 1XCO2 for Windhoek are shown in figure 1.

![Model Test for 1XCO2 for Windhoek](image)

Figure 1. Model test for Temperature at Windhoek.

For comparative purposes, all four models were run again with 2XCO2. The temperature rises resulting varied between an annual average of 2.98°C and 4.72°C over the country and for all the models. The temperature rises varied between 3.32°C and 4.50°C for the country average, with GFD3 as the lowest and GISS as the highest. For the various stations, the rises were very similar, between 3.98°C and 4.08°C for the inland stations and a slightly lower 3.70°C for Pelican Point.

<table>
<thead>
<tr>
<th>Station</th>
<th>GFD3</th>
<th>CCCM</th>
<th>GISS</th>
<th>UK89</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windhoek</td>
<td>3.42</td>
<td>3.89</td>
<td>4.54</td>
<td>4.46</td>
<td>4.08</td>
</tr>
<tr>
<td>Ondangwa</td>
<td>3.26</td>
<td>3.89</td>
<td>4.39</td>
<td>4.19</td>
<td>3.98</td>
</tr>
<tr>
<td>Grootfontein</td>
<td>3.53</td>
<td>3.88</td>
<td>4.58</td>
<td>3.98</td>
<td>3.99</td>
</tr>
<tr>
<td>Keetmanshoop</td>
<td>3.41</td>
<td>3.85</td>
<td>4.72</td>
<td>4.23</td>
<td>4.05</td>
</tr>
<tr>
<td>Pelican Point</td>
<td>2.98</td>
<td>3.85</td>
<td>4.26</td>
<td>3.72</td>
<td>3.70</td>
</tr>
<tr>
<td>Mean</td>
<td>3.32</td>
<td>3.88</td>
<td>4.50</td>
<td>4.12</td>
<td>3.96</td>
</tr>
</tbody>
</table>

Table 2. Scenario Temperature Rises with 2XCO2 according to Four Models.

As a first approximation, therefore, it would be enough to estimate a rise of 4°C for the mean annual temperature for the entire inland area and 3.70°C for the coastal areas, as a result of doubling of the CO₂.

The rise is not, however, constant over the year. Figure 2 shows the scenarios for Windhoek, in which the rise is greater in Winter and Spring than in Summer and Autumn.
Transient Models

Four transient model outputs were used. The GF01 output was provided by the U.S. Country Studies Programme, while the SCENGEN-MAGICS was able to provide several outputs. The three used were from the UK Hadley Centre (UKTR), which is a detailed model including Dynamic Ocean response, and provides a medium scenario. Two others, the Oregon State University (OSU) providing a result with greater rainfall, and the Canadian Climate Centre (CCC), providing much less rainfall, the three more or less thus covering the range of rainfall scenarios output from the various models.

The difference between the transient models and the 2XCO2 models is that the transient models put dates to the changes. These cannot be taken too seriously, because the inputs to the models, e.g. the CO₂ amounts year by year, are only surmised according to the IS92a emissions schedule, and because of the known
uncertainties in the operation of the models themselves. Nevertheless, we have set the scenarios at 40, 70 and 100 years after of 1990 or thereabouts. These results, for certain assumptions, are shown in figure 3 for Windhoek.

Note that, compared to the 2XCO2 models, the temperature rises only become comparable after 100 years or more. Under certain emission assumptions, CO2 never actually doubles, so the two types of models never reach concordance.

The figure shows that temperatures at Windhoek are expected to rise by about 1C in the next 40 years, which is of the same order as the +/- 1C rise which has occurred over the last 50 years.

RAINFALL

The models deal with rainfall rather differently than with temperature. For one thing, the models output daily rainfall, rather than monthly, though it is simple to derive a monthly total. More importantly, though, the models deal with the 2XCO2 by calculating a fractional increase, that is, for example, 2XCO2 rainfall as a ratio to 1XCO2 rainfall.

2XCO2 Models

The table shows the ratio in annual rainfall amounts according to station and model resulting from a doubling of CO2.

<table>
<thead>
<tr>
<th>Station</th>
<th>GFD3</th>
<th>CCCM</th>
<th>GISS</th>
<th>UK89</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windhoek</td>
<td>0.98</td>
<td>1.13</td>
<td>1.16</td>
<td>1.04</td>
<td>1.08</td>
</tr>
<tr>
<td>Ondangwa</td>
<td>1.04</td>
<td>1.05</td>
<td>1.16</td>
<td>1.16</td>
<td>1.10</td>
</tr>
<tr>
<td>Grootfontein</td>
<td>1.08</td>
<td>1.00</td>
<td>1.19</td>
<td>1.24</td>
<td>1.13</td>
</tr>
<tr>
<td>Keetmanshoop</td>
<td>0.98</td>
<td>1.26</td>
<td>1.52</td>
<td>1.20</td>
<td>1.24</td>
</tr>
<tr>
<td>Pelican Point</td>
<td>1.71</td>
<td>1.71</td>
<td>1.05</td>
<td>1.20</td>
<td>1.23</td>
</tr>
</tbody>
</table>

Table 3. Ratios of Rainfall Amounts due to 2XCO2

Because of the different amounts falling at each station, it is not possible to obtain a mean ratio for all stations.

These ratios convert into actual rainfall amounts as shown below (Table 4).
<table>
<thead>
<tr>
<th>Station</th>
<th>Actual</th>
<th>2XCO2</th>
<th>% Increase</th>
<th>Increase (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windhoek</td>
<td>361.0</td>
<td>388.2</td>
<td>8</td>
<td>27.2</td>
</tr>
<tr>
<td>Ondangwa</td>
<td>493.4</td>
<td>543.5</td>
<td>10</td>
<td>50.1</td>
</tr>
<tr>
<td>Grootsfontein</td>
<td>580.7</td>
<td>653.3</td>
<td>13</td>
<td>72.6</td>
</tr>
<tr>
<td>Keetmanshoop</td>
<td>166.5</td>
<td>206.5</td>
<td>24</td>
<td>40.0</td>
</tr>
<tr>
<td>Pelican Point</td>
<td>21.0</td>
<td>25.8</td>
<td>23</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Table 4. Scenario Changes in Rainfall Amounts due to 2XCO2

Transient Models

The transient models do not provide much agreement as to what would happen to rainfall amounts. Figure 4 shows the percentage changes which would occur with the models over the next 100 years.

<table>
<thead>
<tr>
<th>Years after of 1990</th>
<th>Percentage Change</th>
<th>Scenario Amounts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
<td>70</td>
</tr>
<tr>
<td>GF01</td>
<td>-6.1</td>
<td>1.9</td>
</tr>
<tr>
<td>OSU</td>
<td>7.2</td>
<td>13.9</td>
</tr>
<tr>
<td>UKTR</td>
<td>1.8</td>
<td>3.4</td>
</tr>
<tr>
<td>CCC</td>
<td>-3.7</td>
<td>-7.1</td>
</tr>
</tbody>
</table>

Table 5. Percentage Changes in Rainfall Amounts according to the Transient Models

The models indicate anything from a 20% increase to a 20% decrease. The OSU model, as expected, shows a steady increase over the next 100 years. Similarly, the CCCM shows a steady decrease over the same time interval. The UKTR shows a negligible increase, while the GF01 shows an erratic decrease, then an increase, then a sharp decrease.

Figure 4. Percentage Changes of Rainfall at Windhoek according to the Transient Models.
Translated into actual annual rainfalls, the models indicate a range of possible values (for 100 years time) of 290.0mm to 433.9mm, as shown in figure 5.

![Rainfall Changes at Windhoek, Transient](image)

Figure 5. Rainfall Changes at Windhoek according to the Transient Models.

This inconclusive result indicates that more work is required. However, it should be noted that whether rainfall goes up or down, there is little doubt that temperature will increase. This means that evapotranspiration (water requirements of crops) will increase, so that water balance is likely to be adversely affected, which will have implications for both agriculture and water supply.
Appendix 2. GDP by activity, annual changes. Constant 1990 prices – percent
[Source: NPC 1998]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture and forestry products</td>
<td>5.7</td>
<td>7.4</td>
<td>-17.6</td>
<td>-5.7</td>
<td>21.8</td>
<td>0.6</td>
<td>7.4</td>
<td>-10.0</td>
</tr>
<tr>
<td>Commercial</td>
<td>7.0</td>
<td>1.9</td>
<td>-1.4</td>
<td>-8.0</td>
<td>-0.3</td>
<td>-4.9</td>
<td>11.3</td>
<td>-15.2</td>
</tr>
<tr>
<td>Subsistence</td>
<td>3.1</td>
<td>19.7</td>
<td>-48.7</td>
<td>2.8</td>
<td>95.0</td>
<td>9.7</td>
<td>1.8</td>
<td>-1.7</td>
</tr>
<tr>
<td>Fishery products</td>
<td>42.4</td>
<td>18.3</td>
<td>36.5</td>
<td>29.2</td>
<td>5.0</td>
<td>6.1</td>
<td>0.4</td>
<td>-2.8</td>
</tr>
<tr>
<td>Mining and quarrying</td>
<td>-20.9</td>
<td>36.2</td>
<td>4.9</td>
<td>-20.4</td>
<td>11.0</td>
<td>5.1</td>
<td>5.7</td>
<td>4.9</td>
</tr>
<tr>
<td>Diamond mining</td>
<td>-16.3</td>
<td>53.9</td>
<td>22.8</td>
<td>-27.1</td>
<td>10.8</td>
<td>7.1</td>
<td>3.9</td>
<td>-0.7</td>
</tr>
<tr>
<td>Other mining and quarrying</td>
<td>-25.3</td>
<td>17.8</td>
<td>-19.2</td>
<td>-5.6</td>
<td>11.2</td>
<td>2.0</td>
<td>8.7</td>
<td>14.0</td>
</tr>
<tr>
<td>Primary industries</td>
<td>-11.3</td>
<td>26.2</td>
<td>1.3</td>
<td>-12.7</td>
<td>12.6</td>
<td>4.1</td>
<td>5.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>9.2</td>
<td>-4.5</td>
<td>9.5</td>
<td>10.1</td>
<td>5.3</td>
<td>2.9</td>
<td>-6.6</td>
<td>8.1</td>
</tr>
<tr>
<td>Meat processing</td>
<td>2.9</td>
<td>2.8</td>
<td>2.7</td>
<td>2.6</td>
<td>2.8</td>
<td>2.7</td>
<td>2.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Fish processing</td>
<td>36.9</td>
<td>-27.7</td>
<td>48.4</td>
<td>31.9</td>
<td>9.0</td>
<td>0.2</td>
<td>35.2</td>
<td>26.4</td>
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<td>Other manufacturing</td>
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<td>1.8</td>
<td>1.9</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Electricity and water</td>
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<td>38.3</td>
<td>-50.9</td>
<td>24.1</td>
<td>24.5</td>
<td>8.7</td>
<td>-23.8</td>
</tr>
<tr>
<td>Construction</td>
<td>-8.0</td>
<td>-7.0</td>
<td>38.9</td>
<td>11.8</td>
<td>9.1</td>
<td>2.5</td>
<td>7.4</td>
<td>-10.9</td>
</tr>
<tr>
<td>Secondary industries</td>
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<td>-5.2</td>
<td>16.3</td>
<td>2.8</td>
<td>7.1</td>
<td>4.3</td>
<td>-2.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Wholesale and retail trade, repairs</td>
<td>0.5</td>
<td>0.0</td>
<td>5.0</td>
<td>1.5</td>
<td>2.2</td>
<td>4.5</td>
<td>1.8</td>
<td>5.7</td>
</tr>
<tr>
<td>Hotels and restaurants</td>
<td>-22.3</td>
<td>9.4</td>
<td>9.2</td>
<td>-3.4</td>
<td>24.3</td>
<td>13.7</td>
<td>-6.2</td>
<td>10.2</td>
</tr>
<tr>
<td>Transport, and communication</td>
<td>4.0</td>
<td>6.1</td>
<td>3.7</td>
<td>2.0</td>
<td>12.7</td>
<td>10.6</td>
<td>7.1</td>
<td>6.7</td>
</tr>
<tr>
<td>Transport and storage</td>
<td>2.7</td>
<td>1.9</td>
<td>2.7</td>
<td>19.4</td>
<td>13.1</td>
<td>7.1</td>
<td>16.4</td>
<td>19.1</td>
</tr>
<tr>
<td>Post and telecommunications</td>
<td>10.8</td>
<td>6.0</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Finance, real estate, business services</td>
<td>-2.3</td>
<td>2.9</td>
<td>3.0</td>
<td>3.8</td>
<td>0.9</td>
<td>2.2</td>
<td>6.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Financial intermediation</td>
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<td>3.1</td>
<td>-0.2</td>
<td>3.1</td>
<td>13.6</td>
<td>9.3</td>
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<tr>
<td>Financial services indirectly measured</td>
<td>22.1</td>
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<td>3.9</td>
<td>4.4</td>
<td>4.2</td>
<td>7.1</td>
<td>7.1</td>
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<tr>
<td>Real estate and business services</td>
<td>1.9</td>
<td>3.4</td>
<td>3.5</td>
<td>2.5</td>
<td>2.7</td>
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<tr>
<td>Owner-occupied dwellings</td>
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<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
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</tr>
<tr>
<td>Other real estate and business services</td>
<td>1.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>2.5</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Community, social and personal services</td>
<td>2.2</td>
<td>1.8</td>
<td>1.3</td>
<td>2.8</td>
<td>-3.0</td>
<td>-0.7</td>
<td>-1.2</td>
<td>-0.6</td>
</tr>
<tr>
<td>Producers of government services</td>
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<td>14.8</td>
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<td>4.1</td>
<td>1.8</td>
<td>0.7</td>
<td>1.6</td>
<td>3.0</td>
</tr>
<tr>
<td>Other producers</td>
<td>1.6</td>
<td>1.6</td>
<td>2.0</td>
<td>2.9</td>
<td>2.4</td>
<td>2.0</td>
<td>2.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Tertiary industries</td>
<td>2.8</td>
<td>8.4</td>
<td>6.2</td>
<td>3.2</td>
<td>3.3</td>
<td>3.0</td>
<td>2.7</td>
<td>4.1</td>
</tr>
<tr>
<td>All industries at basic prices</td>
<td>-1.7</td>
<td>11.6</td>
<td>6.0</td>
<td>-2.3</td>
<td>6.8</td>
<td>3.6</td>
<td>2.6</td>
<td>2.4</td>
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<td>Import duties</td>
<td>12.9</td>
<td>-2.0</td>
<td>6.7</td>
<td>-1.5</td>
<td>10.4</td>
<td>-3.4</td>
<td>8.4</td>
<td>-7.2</td>
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<tr>
<td>Other taxes on products</td>
<td>-3.6</td>
<td>5.1</td>
<td>8.8</td>
<td>1.5</td>
<td>3.8</td>
<td>4.7</td>
<td>3.9</td>
<td>-0.2</td>
</tr>
<tr>
<td>GDP at market prices</td>
<td>-1.2</td>
<td>10.4</td>
<td>6.3</td>
<td>-2.0</td>
<td>6.7</td>
<td>3.4</td>
<td>2.9</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Appendix 3. Namibia’s National Development Objectives and Targets  
[Source: NDP 1]

Economic
- Formulate and carry out a vigorous and top-priority human resources development programme open to all Namibians, especially the unemployed
- Expand the role of the private sector and foreign investment in the economy
- Maintain inflation at a level not exceeding that of Namibia’s main trading partners
- Maintain CMA membership and parity with the rand and to work with CMA partners to liberalise exchange controls
- Improve levels of household food security nationally with an ultimate aim of achieving food self-sufficiency
- Diversify import sources and export markets to increase trade with other southern African countries
- Promote productive sectors with high potential for growth such as manufacturing, fisheries, tourism, agriculture and mining
- Promote national development of appropriate science and technology

Social
- Reduce the population growth rate to below 3% by 2010
- Reduce the total fertility rate to 4.5 children per woman by 2010
- Increase life expectancy to 63 years by 2000
- Promote the development of sport and indigenous culture
- Increase the literacy rate to 80% by the year 2000

Political
- Reduce existing regional imbalances
- Promote increased participation of women, youth and other marginalised groups in economic development activities
<table>
<thead>
<tr>
<th>BULK WATER SUPPLY 1996/1997</th>
<th>RURAL WATER SUPPLY</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOTAL</td>
<td>Ground</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>Ground</td>
</tr>
<tr>
<td>Livestock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>communal</td>
<td>16.6</td>
<td>1.4</td>
</tr>
<tr>
<td>commercial</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Crops</td>
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<td></td>
</tr>
<tr>
<td>communal</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>commercial</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diamond</td>
<td>5.5</td>
<td>2.9</td>
</tr>
<tr>
<td>Other Mining</td>
<td>5.5</td>
<td>2.9</td>
</tr>
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<td>Manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish Processing</td>
<td>5.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>48</td>
<td>3.3</td>
</tr>
<tr>
<td>Services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td>5.4</td>
<td>3.7</td>
</tr>
<tr>
<td>Utilities</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Construction</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Trade</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.8</td>
<td>0.5</td>
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<tr>
<td>Hotels/Rest.</td>
<td>(Tourism)</td>
<td>0.9</td>
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<td>Communications</td>
<td>0.2</td>
<td>0.1</td>
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<tr>
<td>FIREB</td>
<td>0.7</td>
<td>0.5</td>
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<td>Self-owned housing</td>
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<tr>
<td>Social services</td>
<td></td>
<td>0.8</td>
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<tr>
<td>Government</td>
<td></td>
<td>2.4</td>
</tr>
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<td></td>
<td></td>
<td>49.5</td>
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<td></td>
<td></td>
<td>39.2</td>
</tr>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>231.2</td>
</tr>
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<td></td>
<td>TOTAL</td>
<td>104.6</td>
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<tr>
<td></td>
<td>Gardens on stock Farm</td>
<td>243</td>
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<tr>
<td></td>
<td>TOTAL</td>
<td>104.6</td>
</tr>
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</table>
[Source:- In Dewdney, 1996]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>million m³</td>
<td>% of total</td>
<td>million m³</td>
</tr>
<tr>
<td>Department of Water Affairs</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>livestock</td>
<td>1</td>
<td>1%</td>
<td>8</td>
</tr>
<tr>
<td>irrigation (Hardap)</td>
<td>28</td>
<td>18%</td>
<td>25</td>
</tr>
<tr>
<td>urban</td>
<td>18</td>
<td>12%</td>
<td>51</td>
</tr>
<tr>
<td>mines</td>
<td>14</td>
<td>9%</td>
<td>6</td>
</tr>
<tr>
<td>Rural consumption (non DoWA), rough estimates</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>livestock</td>
<td>25</td>
<td>16%</td>
<td>30</td>
</tr>
<tr>
<td>domestic rural</td>
<td>7</td>
<td>4%</td>
<td>10</td>
</tr>
<tr>
<td>irrigation</td>
<td>60</td>
<td>39%</td>
<td>110</td>
</tr>
<tr>
<td>Estimated total</td>
<td></td>
<td></td>
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<tr>
<td>livestock</td>
<td>26</td>
<td>17%</td>
<td>38</td>
</tr>
<tr>
<td>irrigation</td>
<td>88</td>
<td>58%</td>
<td>135</td>
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<td>domestic rural</td>
<td>7</td>
<td>4%</td>
<td>10</td>
</tr>
<tr>
<td>urban</td>
<td>18</td>
<td>12%</td>
<td>51</td>
</tr>
<tr>
<td>mines</td>
<td>14</td>
<td>9%</td>
<td>6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>153</td>
<td>100%</td>
<td>239</td>
</tr>
<tr>
<td>GROUP</td>
<td>Number of endemics</td>
<td>Number of species described</td>
<td>% endemism of known species</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------------</td>
<td>-----------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Viruses, Monerans Protists.</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Fungi</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Lichens</td>
<td>At least one genus and several species.</td>
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<td>Unknown</td>
</tr>
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<td>Plants</td>
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<td>4138</td>
<td>17</td>
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<tr>
<td>Poriferans</td>
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<tr>
<td>Cnidarians</td>
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<td>Unknown</td>
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<tr>
<td>Platyhelminthes</td>
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<td>9</td>
<td>Unknown</td>
</tr>
<tr>
<td>Ectoproctans</td>
<td>Unknown</td>
<td>5</td>
<td>Unknown</td>
</tr>
<tr>
<td>Nematodes</td>
<td>1</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Annelids</td>
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<td>27</td>
<td>Unknown</td>
</tr>
<tr>
<td>Molluscs</td>
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<td>104</td>
<td>9</td>
</tr>
<tr>
<td>Arachnids</td>
<td>164</td>
<td>1411</td>
<td>12</td>
</tr>
<tr>
<td>Crustaceans</td>
<td>39</td>
<td>142</td>
<td>28</td>
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<tr>
<td>Myriapods</td>
<td>13</td>
<td>45</td>
<td>25</td>
</tr>
<tr>
<td>Insects</td>
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<td>6331</td>
<td>24</td>
</tr>
<tr>
<td>Frogs</td>
<td>6</td>
<td>46</td>
<td>13</td>
</tr>
<tr>
<td>Fish</td>
<td>5</td>
<td>115</td>
<td>4</td>
</tr>
<tr>
<td>Reptiles</td>
<td>59</td>
<td>250</td>
<td>24</td>
</tr>
<tr>
<td>Mammals</td>
<td>14</td>
<td>200</td>
<td>7</td>
</tr>
<tr>
<td>Birds</td>
<td>14</td>
<td>658</td>
<td>2</td>
</tr>
</tbody>
</table>
Appendix 7. **Main water co-ordinating committees established between Namibia and her neighbours** [Source: P.W.Tarr, in prep.]

<table>
<thead>
<tr>
<th>Title of Agreement, signatories and date</th>
<th>Primary objectives</th>
</tr>
</thead>
</table>
| **Joint Permanent Technical Commission on the Kunene River (JPTC) between Angola and Namibia.**  
Signed: 18/09/1990 | a) Ensure maximum beneficial regulation of water flow at Gove Dam for optimal power generation at Ruacana and to control water abstraction in the middle-Kunene River.  
b) Ensure continuous operation & adequate maintenance of water pumping works at Caluque and Ruacana.  
c) To allow the JPTC to evaluate future schemes on the river for electricity needs of both countries. |
| **Joint Permanent Water Commission (JPWC) Between Namibia and Botswana.**  
(Signed: 13/11/1990) | Advise both Parties on the following:  
a) measures & arrangements to determine the potential of water resources from rivers of common interest;  
b) reasonable demand for water from common resources;  
c) establishing the criteria for allocation & utilisation of common water;  
d) prevention & control of aquatic weeds and pollution. |
| **Permanent Water Commission (PWC) between Namibia and South Africa.**  
(and a specific agreement on The Vioolsdrift and Noordoewer Joint Irrigation Scheme)  
(Signed: 14/09/1992) | Advise both Parties on the following:  
a) measures & arrangements to determine the potential of water resources from rivers of common interest;  
b) reasonable demand for water from common resources;  
c) establishing the criteria for allocation & utilisation of common water;  
d) investigations relating to the development of waters, including construction, operation & maintenance of works;  
e) prevention & control of aquatic weeds and pollution;  
f) measures to alleviate short-term problems from water shortages during droughts, taking into account stored water and requirements in respective territories at the time. |
| **Permanent Okavango River Basin Water Commission (OKAKOM) between Angola, Botswana and Namibia.**  
(Signed: 15/09/1994) | Advise all Parties on the following:  
a) Measures and arrangements to determine the long term safe yield of the water available from all potential resources in the Okavango River  
b) the reasonable demand for water from consumers in the Okavango R.  
c) criteria for conservation, equitable allocation and sustainable utilisation of water in the Okavango River  
d) investigations relating to development of waters, including construction, operation & maintenance of works;  
e) prevention & control of aquatic weeds and pollution;  
f) measures to alleviate short-term problems from water shortages during droughts, taking into account stored water and requirements in respective territories at the time. |
Appendix 7(a).

REDUCED RAINFALL AND THE PROPOSED DONKERSAN DAM ON THE KUISEB RIVER

[ Jacobson et al., 1995; Mostert, 1998]

BACKGROUND: The Kuiseb River passes through the Namib/Naukluft Park. Most of its catchment area (15 500 km$^2$) falls on private farmland in the Khomas Hochland (Figure 5.7). Besides providing water for underground aquifers (near Rooibank) which service the coastal towns of Walvis Bay and Swakopmund, the ground water reserves of the Kuiseb support a dense, narrow strip of riparian vegetation and associated wildlife. Communal farmers residing near Homeb, Gobabeb and Swartbank depend on these forested areas for veldkos, goat forage, fuelwood and construction materials.

In addition to three state water schemes (at Gobabeb, Rooibank and Friedenau Dam – Figure 5.7), several small dams have been built on private farms in the Kuiseb’s headwaters. These developments have cumulatively altered the availability of water within the catchment and threatened the environment and livelihoods of the downstream communities.

The potential of new dams is being evaluated within the Kuiseb catchment area. The Central Areas Water Master Plan (CAWMP) identifies a site on the farm Donkersan, as a possible future source of water for Windhoek and the Coast. MAWRD hydrologists have evaluated the rainfall runoff and the potential yield of the proposed dam under current climatic conditions and possible future conditions that display a reduction in rainfall.

METHODS: Runoff records from the Schlesien hydrological station were used for the evaluation of runoff and yield for the proposed Donkersan Dam. The following procedure was followed:

Based on data from 52 weather bureau rainfall stations, areal rainfall totals for the entire catchment for all months since 1924/25 were produced using a multiquadratic surface fitting technique.

The NAMRON rainfall/runoff model was used to calibrate the hydrological routing of these monthly rainfall volumes with observed flow records (from 1961/62 to 1995/96) through the Donkersan catchment area. Continued

NAMRON was then used to extrapolate the observed flow records back to 1927/1928 to obtain a long synthetic monthly flow sequence.

Stochastic runoff and rainfall records of 1000 years were produced using the NAMREC model. Safe yields for the proposed Donkersan site were determined using the RESSIM programme.

NAMRED and the programs SPILL were then used to determine new synthesised runoff records and safe dam yields if rainfall decreased by 5%, 10% and 15%.

RESULTS

The observed and synthesised Schlesien runoff records and the synthesised runoff records after incorporating a 5%, 10% and 15% reduction factor are depicted in Table 5.6. The expected 80% and 95% safe yield and reduced 80% and 95% safe yield as a result of reduced reductions in rainfall for the proposed Donkersan Dam are depicted in Table 5.7.

CONCLUSIONS

A reduction in rainfall will result in exponentially larger reductions in runoff and yield potential of dams.
Table 5.6 Observed (1961/62 to 1995/96) and decreasing simulated (1927/28 to 1995/96) runoff data for the proposed Donkersan Dam [Mostert 1998]

<table>
<thead>
<tr>
<th>Annual Statistic</th>
<th>Observed Runoff Record</th>
<th>RAINFALL REDUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Synthesised Runoff Record</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Average (Mm³)</td>
<td>15.19</td>
<td>18.91</td>
</tr>
<tr>
<td>Percentage change in runoff</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Years</td>
<td>35</td>
<td>69</td>
</tr>
</tbody>
</table>

Table 5.7 Yield reduction of the proposed Donkersan Dam as a result of decreased rainfall [Mostert 1998]

<table>
<thead>
<tr>
<th>Storage volume estimations (Mm³)</th>
<th>Full supply capacity</th>
<th>Yields obtained from the stochastic runoff record</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dead storage</td>
<td>80% reliable safe yield (Mm³)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rainfall reduction factor (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35.00</td>
</tr>
<tr>
<td>Percentage reduction in yield</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

NB: Dead storage is calculated at 5% of the full capacity. The 80% and 95% safe yields, expressed in Mm³, represent the volume of water available per annum for extraction purposes with a reliability of 80% and 95% respectively.
Appendix 8. Some Namibian species of economic value
[Barnard 1998]

<table>
<thead>
<tr>
<th>Species or group</th>
<th>Description/source of value</th>
<th>Conservation threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gracilaria</td>
<td>Red marine alga, mariculture</td>
<td>Harvesting sustainability unknown</td>
</tr>
<tr>
<td>Terfezia pfeilli</td>
<td>Truffle-like fungus</td>
<td>Harvested on small scale (subsistence and commercial)</td>
</tr>
<tr>
<td>Termitomyces schimperi</td>
<td>Large delicious mushroom, symbiotic with termites</td>
<td>Threatened by overexploitation</td>
</tr>
<tr>
<td>Harpagophyllum procumbens</td>
<td>Kalahari medicinal plant</td>
<td>Threatened by overexploitation</td>
</tr>
<tr>
<td>Pterocarpus angolensis</td>
<td>Subtropical tree used for carvings and furniture</td>
<td></td>
</tr>
<tr>
<td>Cucurbitaceae</td>
<td>Melons, agricultural potential</td>
<td>Unknown</td>
</tr>
<tr>
<td>Sclerocarya birrea</td>
<td>Subtropical fruit tree with diverse subsistence values</td>
<td>Often protected informally</td>
</tr>
<tr>
<td>Cleome spp.</td>
<td>'Wild spinach,' subsistence use</td>
<td>Unknown</td>
</tr>
<tr>
<td>Lepidoptera</td>
<td>Butterflies collected and traded</td>
<td>Some threatened by overexploitation?</td>
</tr>
<tr>
<td>Mantica horni, Mantichora spp.</td>
<td>Rare collectors' insects</td>
<td>Threatened by overexploitation?</td>
</tr>
<tr>
<td>Imbrasia belina</td>
<td>Mopane caterpillars</td>
<td>Threatened by overexploitation?</td>
</tr>
<tr>
<td>Usta wallengreni</td>
<td>Mopane caterpillars</td>
<td>Threatened by overexploitation?</td>
</tr>
<tr>
<td>Termites</td>
<td>Some destroy grazing</td>
<td>Unknown</td>
</tr>
<tr>
<td>Locusts</td>
<td>Some are crop pests</td>
<td></td>
</tr>
<tr>
<td>Mosquitoes</td>
<td>Some are disease vectors</td>
<td></td>
</tr>
<tr>
<td>Alien invasive insects</td>
<td>Livestock pests or crop pathogens</td>
<td></td>
</tr>
<tr>
<td>Macrobrachium vollenhoveni</td>
<td>Edible freshwater shrimp</td>
<td>Threatened by Epupa Dam</td>
</tr>
<tr>
<td>Murella dubia</td>
<td>Edible freshwater mussel</td>
<td>Unknown, harvested for subsistence</td>
</tr>
<tr>
<td>Bulinus globosus</td>
<td>Human schistosome vector</td>
<td></td>
</tr>
<tr>
<td>Bulinus tropicus</td>
<td>Livestock paramphistome vector</td>
<td></td>
</tr>
<tr>
<td>Biomphalaria pfeifferi</td>
<td>Human schistosome vector</td>
<td></td>
</tr>
<tr>
<td>Lymnaea natalensis</td>
<td>Livestock liverfluke vector</td>
<td></td>
</tr>
<tr>
<td>Chaceon maritae</td>
<td>Deep-sea crab, harvested</td>
<td></td>
</tr>
<tr>
<td>Jasus Ilandii</td>
<td>Spiny rock lobster, harvested</td>
<td></td>
</tr>
<tr>
<td>Sardinops ocellatus</td>
<td>Pilchard, harvested</td>
<td>Past bottlenecks via overharvesting</td>
</tr>
<tr>
<td>Engraulis capensis</td>
<td>Anchovy, harvested</td>
<td>Threatened by overexploitation?</td>
</tr>
<tr>
<td>Pyxicephalus adspersus</td>
<td>Bullfrog, subsistence use</td>
<td>Threatened by overexploitation/ trade</td>
</tr>
<tr>
<td>Tortoises, six species</td>
<td>Subsistence use, pet trade</td>
<td>Threatened by illegal trade</td>
</tr>
<tr>
<td>Python anchietae</td>
<td>Dwarf python, pet trade</td>
<td></td>
</tr>
<tr>
<td>Bitis spp.</td>
<td>Dwarf adders, pet trade</td>
<td></td>
</tr>
<tr>
<td>Francolins</td>
<td>Gamebirds, harvested</td>
<td>Threatened by illegal trade</td>
</tr>
<tr>
<td>Quelea quelea</td>
<td>Major pest bird on crops</td>
<td>Threatened by illegal trade</td>
</tr>
<tr>
<td>Arctocephalus pusillus</td>
<td>Cape fur seal, harvested</td>
<td></td>
</tr>
<tr>
<td>Manis temminckii</td>
<td>Cape pangolin, medicinal trade</td>
<td></td>
</tr>
<tr>
<td>Diceros bicornis</td>
<td>Black rhino, horn trade</td>
<td>Secure in southern Africa</td>
</tr>
<tr>
<td>Loxodonta africana</td>
<td>African elephant, ivory trade</td>
<td></td>
</tr>
</tbody>
</table>
**Appendix 9. Areas of special ecological importance in Namibia**  
[Barnard 1998]

<table>
<thead>
<tr>
<th>Category</th>
<th>Site</th>
<th>Known distinctive values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast wetlands</td>
<td>Zambezi River frontage*</td>
<td>Biotic richness; red data birds, plants, etc.</td>
</tr>
<tr>
<td></td>
<td>Okavango River frontage*</td>
<td>Biotic richness; threatened plants and insects</td>
</tr>
<tr>
<td></td>
<td>Isolated pools, eastern Caprivi</td>
<td>Endemic Caprivi killifish (<em>Nothobranchius</em>)</td>
</tr>
<tr>
<td></td>
<td>Impalila Island</td>
<td>Biotic richness, red data spp., unique vegetation communities on basalt</td>
</tr>
<tr>
<td>Border rivers</td>
<td>Lower Kunene River</td>
<td>Endemic fish; edible oysters and shrimps; habitat threatened by Epupa Dam</td>
</tr>
<tr>
<td></td>
<td>Lower Orange River</td>
<td>One fish endemic to lower river; two others endemic to the river basin are threatened</td>
</tr>
<tr>
<td>Ephemeral pans</td>
<td>Tsumkwe Pans **</td>
<td>Biotic richness; endemic crustaceae; red data birds; habitat/water source for people and wildlife</td>
</tr>
<tr>
<td></td>
<td>Cuvelai Basin/ Etosha pans</td>
<td>Biotic richness; important ephemeral pan habitat; breeding red data birds; resources for people; significant basis of Namibia's tourism industry</td>
</tr>
<tr>
<td>Ephemeral rivers</td>
<td>particularly Ugab, Huab,</td>
<td>Biotic richness; large desert-dwelling mammals; high value for human subsistence and tourism</td>
</tr>
<tr>
<td></td>
<td>Hoanib and Hoarusib Rivers</td>
<td></td>
</tr>
<tr>
<td>Karst caves/ sinkholes and</td>
<td>Aigamas, Arnhem and Dragon's Breath Caves; Lakes Guinas and</td>
<td>Endangered cave catfish (<em>Clarias cavernicola</em>); endemic Ojikoto tilapia (<em>Tilapia guinasana</em>); endemic or restricted crustaceae; habitats</td>
</tr>
<tr>
<td>springs</td>
<td>Ojikoto</td>
<td>threatened by water abstraction</td>
</tr>
<tr>
<td>Coastal wetlands</td>
<td>Kunene River mouth</td>
<td>Transition zone; sea turtles; migrant shorebirds</td>
</tr>
<tr>
<td></td>
<td>Orange River mouth</td>
<td>Migrant shorebirds (Ramsar site)</td>
</tr>
<tr>
<td></td>
<td>Sandwich Harbour</td>
<td>Biotic richness; 36 fish spp; migrant shorebirds (important Ramsar site); red data birds</td>
</tr>
<tr>
<td></td>
<td>Walvis Bay lagoon</td>
<td>Biotic richness; migrant shorebirds (most important Ramsar site)</td>
</tr>
<tr>
<td></td>
<td>Lüderitz lagoon</td>
<td>Migrant shorebirds; seabird breeding site</td>
</tr>
<tr>
<td></td>
<td>Cape Cross</td>
<td>Cape fur seal and seabird breeding site</td>
</tr>
<tr>
<td>Coastline</td>
<td>entire coast</td>
<td>Biotic richness (arachnids, birds, lichens)</td>
</tr>
<tr>
<td>Offshore islands</td>
<td>All 18 islands plus artificial guano platforms</td>
<td>Seabird breeding sites; rich marine fauna</td>
</tr>
<tr>
<td>Mountains and inselbergs</td>
<td>general:</td>
<td>Phylogenetic relicts; high endemcity</td>
</tr>
<tr>
<td></td>
<td>Brandberg</td>
<td>High endemcity (plants, reptiles, insects); major rock art sites; threatened by tourism pressure</td>
</tr>
<tr>
<td></td>
<td>Otjihapa Mountains</td>
<td>Highly restricted-range and vulnerable biota (shorthead barb; butterfly <em>Acraea brainei</em>)</td>
</tr>
<tr>
<td></td>
<td>Otavi Mountains</td>
<td>Biotic richness (plants, birds)</td>
</tr>
<tr>
<td></td>
<td>Aurus Mountains</td>
<td>Botanical richness and endemism, scenic value</td>
</tr>
<tr>
<td></td>
<td>Karas Mountains</td>
<td>Botanical richness; endemic insects, lizards</td>
</tr>
<tr>
<td></td>
<td>Waterberg Plateau</td>
<td>Biotic richness (lichens, plants, birds); Cape griffon breeding site, endemic insects</td>
</tr>
<tr>
<td></td>
<td>Eroango Mountains</td>
<td>Botanical richness; endemic vertebrates</td>
</tr>
</tbody>
</table>
### Areas of special ecological importance in Namibia cont.

<table>
<thead>
<tr>
<th>Category</th>
<th>Site</th>
<th>Known distinctive values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountains and inselbergs (cont.)</td>
<td>Auas Mountains</td>
<td>Highly-restricted range butterflies, lizard</td>
</tr>
<tr>
<td></td>
<td>Hunsberge</td>
<td>Vertebrate richness and endemism</td>
</tr>
<tr>
<td></td>
<td>Brukkaros</td>
<td>Endemic rodents</td>
</tr>
<tr>
<td></td>
<td>Tiras Mountains</td>
<td>Endemic reptiles</td>
</tr>
<tr>
<td></td>
<td>Campbell's Valley, near Helmeringhausen</td>
<td>Highly restricted-range lizard, <em>Cordylus campbell</em></td>
</tr>
<tr>
<td>Granite domes</td>
<td>Omaruru district domes</td>
<td>Biotic richness and endemism (vertebrates, probably other taxa). Habitats are on private and communal farmland and need protection</td>
</tr>
<tr>
<td>Namib gravel plains</td>
<td>Coastal fog belt</td>
<td>Biotic richness and endemism (lichens, arachnids, insects); habitat threatened by off-road driving</td>
</tr>
<tr>
<td>Winter rainfall zone</td>
<td>Aus area; <em>Sperrgebiet</em> incl. Aurusberg, Roter Kamm</td>
<td>Biotic richness and endemism (succulent plants, arachnids, insects); scenic grandeur</td>
</tr>
<tr>
<td>Sand dunes</td>
<td>Southern Namib dune 'sea'</td>
<td>High endemicity (arachnids, insects, lizards)</td>
</tr>
<tr>
<td>Major tourism areas</td>
<td>Spitzkoppe</td>
<td>Biotic richness and endemism; habitat threatened somewhat by tourism pressure</td>
</tr>
<tr>
<td></td>
<td>entire Kaokoveld</td>
<td>High endemicity; habitat and cultural integrity threatened by tourism pressure</td>
</tr>
<tr>
<td></td>
<td>Sesriem Canyon</td>
<td>Scenic grandeur; habitat threatened by tourism pressure</td>
</tr>
</tbody>
</table>

* River frontage includes riparian belt, floodplains including oxbow lakes and other features, open water and river bed. Quartz outcrop biota near Andara on the Okavango River merits special attention.
** Tsumkwe Pans are widely known as "Bushmanland Pans" and have wildlife tourism potential.
Appendix 10. A broad outline of Namibia’s future biodiversity strategy.
[Barnard 1998]

I. CONSERVATION ACTIONS
   * systematics, ID, & basic cons. status research
   * conservation planning and management
   * protected areas
   * non-protected areas
   * threatened species, genomes and habitats
   * indigenous knowledge
   * information management

II. INTEGRATING POLICY AND PLANNING
    * national policies
    * agriculture, including pastoralism
    * fisheries
    * forestry, water and catchment management
    * tourism and wildlife
    * genetic resources

III. MANAGING THREATENING PROCESSES
     * habitat alteration
     * alien species & genetically modified organisms
     * pollution
     * poor land management, incl. fire management
     * climate change
     * environmental assessment
     * habitat rehabilitation

IV. AWARENESS AND INVOLVEMENT
    * education and training
    * incentives
    * natural and cultural heritage
    * building a civil society
Appendix 11. Economic loss of cattle and smallstock in Namibia due to drought and plant poisonings (1990-1997) [DVS, unpublished data].

| Year | Cattle | | | | | Small stock | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Drought | Deaths per 100000 | Poisonous plants | Deaths per 100000 | | Drought | Deaths per 100000 | Poisonous plants | Deaths per 100000 |
| 1990 | 1452 (1) | 101 | 347 (5) | 24 | 4185 (3) | 92 | 1965 (8) | 43 |
| 1991 | 341 (3) | 23 | 458 (1) | 31 | 3187 (3) | 74 | 1199 (8) | 28 |
| 1992 | 2667 (1) | 171 | 834 (3) | 53 | 25981 (1) | 588 | 3193 (6) | 72 |
| 1993 | 11023 (1) | 731 | 848 (3) | 56 | 82977 (1) | 2364 | 4179 (5) | 119 |
| 1994 | 238 (6) | 17 | 566 (3) | 39 | 11534 (1) | 319 | 2374 (6) | 66 |
| 1995 | 4422 (1) | 313 | 745 (3) | 53 | 26627 (1) | 754 | 1611 (7) | 46 |
| 1996 | 7912 (1) | 634 | 1376 (3) | 110 | 39107 (1) | 1261 | 8140 (3) | 263 |
| 1997 | 5189 (1) | 444 | 1413 (2) | 121 | 29626 (1) | 865 | 6452 (3) | 186 |

Note: Numbers in brackets behind numbers of deaths indicate chronological position in the list of losses i.e. (1) most common cause of death (2) Second most common cause of death etc.
The main objectives of this policy are to:

- Ensure that household food security is not compromised by drought;
- Encourage and support farmers to adopt self-reliant approaches to drought risk;
- Preserve adequate reproductive capacity in livestock herds in affected areas during drought periods;
- Ensure the continuous supply of potable water to communities, and particularly to their livestock, schools and clinics;
- Minimise the degradation of the natural resource base during droughts;
- Enable rural inhabitants and the agricultural sector to recover quickly following drought;
- Ensure that the health status of all Namibians is not threatened by the effects of drought;
- Finance drought relief programs efficiently and effectively by establishing an independent and permanent National Drought Fund.

A key feature of this new policy is its focus on reducing vulnerability to drought in the long-term. Instead of financing regular large-scale drought relief programmes, the Government will create an enabling policy environment and promote drought mitigating technologies and practices.