Climate Change Vulnerability and Adaptation Assessment
for Namibia's Biodiversity and Protected Area System

May 2010

Ministry of Environment and Tourism
Directorate of Parks & Wildlife Management

Republic of Namibia

Ministry of Environment and Tourism

This report was commissioned by the Ministry of Environment and Tourism (MET) with funding from the UNDP/GEF supported Strengthening the Protected Area Network (SPAN) Project.

Authors: Jane Turpie, Guy Midgley, Chris Brown, Jon Barnes, John Pallett, Phillip Desmet, Jacquie Tarr & Peter Tarr

Ministry of Environment and Tourism
FGI Building, Post St. Arcade
P/Bag 13346, Windhoek
Tel: (+264 61) 284 2111

Directorate of Parks and Wildlife Management
PZN Building, Northen Industria
P/Bag 13306, Windhoek
Tel: (+264 61) 284 2518

Energy and Environment Unit
UN House, 1st Floor
38 Stein Street, Klein Windhoek
P/Bag 13329, Windhoek
Tel: (+264 61) 204 6111

Global Environmental Facility via the United Nations Development Programme
UN House, 1st Floor
38 Stein Street, Klein Windhoek
P/Bag 13329, Windhoek
Tel: (+264 61) 204 6111

Cover Photo: Peter Tarr

Ministry of Environment and Tourism

This report was commissioned by the Ministry of Environment and Tourism (MET) with funding from the UNDP/GEF supported Strengthening the Protected Area Network (SPAN) Project.

Authors: Jane Turpie, Guy Midgley, Chris Brown, Jon Barnes, John Pallett, Phillip Desmet, Jacquie Tarr & Peter Tarr

Ministry of Environment and Tourism
FGI Building, Post St. Arcade
P/Bag 13346, Windhoek
Tel: (+264 61) 284 2111

Directorate of Parks and Wildlife Management
PZN Building, Northen Industria
P/Bag 13306, Windhoek
Tel: (+264 61) 284 2518

Energy and Environment Unit
UN House, 1st Floor
38 Stein Street, Klein Windhoek
P/Bag 13329, Windhoek
Tel: (+264 61) 204 6111

Global Environmental Facility via the United Nations Development Programme
UN House, 1st Floor
38 Stein Street, Klein Windhoek
P/Bag 13329, Windhoek
Tel: (+264 61) 204 6111

Cover Photo: Peter Tarr

ACKNOWLEDGEMENTS

This study was funded by GEF through the UNDP Eastern and Southern Africa Regional Office. The authors would like to thank the following people for their assistance:

- UNDP staff for their guidance and comments on the draft deliverables, particularly Lebogang Motlana, Martha Mwandingi, Nik Sekhran, Pradeep Kurukulasuriya, Rob Kelly, and Romie Nghiulikwa;
- Namibia's Ministry of Environment and Tourism for support and review;
- Morgan Hauptfleisch and Gudrun Denker of SAIEA, for project management and administration;
- Katrina Dierkes for production of the GIS maps;
- Barry Clark and Karen Tunley of Anchor Environmental, for inputs on the marine components;
- Johan le Roux of Directorate of Forestry (Namibia) for inputs on fire;
- Nathan Gichohi, Gwyneth Wilson, Deo Tuyisingize, Deo Kujirakwinja, Mike Marais, Yvonne Githiora, Ian Kisson, Sharon George, Allison Skidmore, Ben Heermans and Christina Mosely, for enumeration of the tourism survey and inputs into the analysis and write-up;
- Anja Teroerde of Anchor Environmental for German translation, enumeration and field trip logistical organization; and
- Sabrina Chesterman and Gwyneth Wilson of Anchor Environmental for assistance with report production

This report was produced by:

Anchor Environmental Consultants, Suite 8, Steenberg House, Silverwood Road, Tokai, 7945; www.anchorenvironmental.co.za

Namibia Nature Foundation, PO Box 245, Windhoek, Namibia; www.nnf.org.na

Southern African Institute for Environmental Assessment, PO Box 6322, Windhoek, Namibia; www.saiea.com

TABLE OF CONTENTS

ACKNOWLEDGEMENTS I

LIST OF ABBREVIATIONS VII

EXECUTIVE SUMMARY X

1 INTRODUCTION 1

1.1 Background 1
1.2 Objectives of the study 1
1.3 Study area and scope of the study 2
1.4 Limitations of the study 3

2 GEOGRAPHY, CLIMATE AND BIODIVERSITY 4

2.1 Geography and climate of Namibia 4
2.2 Terrestrial biomes, biodiversity and productivity 7
2.2.1 Tree and shrub savanna 8
2.2.2 Nama Karoo 8
2.2.3 Namib Desert 8
2.2.4 Succulent Karoo 9
2.2.5 Biodiversity and endemism hotspots 9
2.2.6 Distribution of terrestrial primary productivity 11
2.3 Inland and coastal rivers and wetlands 12
2.3.1 Inland rivers and wetlands 12
2.3.2 Coastal wetlands 14
2.4 Coastal habitats and biodiversity 14
2.4.1 Sandy shores 15
2.4.2 Rocky Shores 15
2.4.3 Islands 16
2.4.4 Subtidal benthic communities 16
2.4.5 Near-shore fish 16
2.4.6 Marine mammals and reptiles 17
2.5 Shelf habitats and biodiversity 17
2.5.1 Plankton 17
2.5.2 Fish 18
2.5.3 Pelagic seabirds 18

3 LAND USE AND CONSERVATION 19

3.1 The protected areas network 19
3.1.1 Biome and vegetation coverage 19
3.2 Marine and Coastal Conservation 23
3.3 Main land uses outside of protected areas 24
3.4 Vision for the development of Namibia's Protected Area system 27
3.4.1 The Parks Vision 27
3.4.2 MET's current mandate 29

4 THE VALUE OF LAND AND NATURAL RESOURCES 31

4.1 Introduction 31
4.2 Direct use values 31
4.2.1 Livestock production 31
4.2.2 Crop production 32
4.2.3 Wildlife tourism 34
4.2.4 Harvesting of wildlife and plant resources 35
4.2.5 Summary 37
4.3 Indirect value from ecosystem services 38
4.3.1 Carbon sequestration 38
4.3.2 Water supply and regulation 40
4.3.3 Refugia 40
4.4 Non-use values 41

5 CLIMATE CHANGE PREDICTIONS 42

5.1 Introduction 42
5.2 Observed trends 42
5.2.1 Temperature 42
5.2.2 Precipitation, streamflows and water balance 43
5.2.3 Sea Level Rise 43
5.3 Existing climate projections for Namibia 43
5.3.1 Projected temperature and evaporation changes 44
5.3.2 Projected changes in precipitation 45
5.4 Interpretation of projections for this study 46

6 DIRECT IMPACTS ON ECOSYSTEMS AND BIODIVERSITY 51

6.1 Introduction 51
6.2 Sea-level rise 52
6.3 Change in freshwater flows 53
6.4 Changes in fire risk 55
6.4.1 Introduction 55
6.4.2 The current state of affairs 56
6.4.3 Trends in fire frequency and impacts of burning practices 58
6.4.4 Impact of climate change 58
6.5 Impacts on marine habitats and biodiversity 59
6.6 Impacts on wetlands and their biodiversity 61
6.7 Impacts on terrestrial habitats and productivity 61
6.7.1 Introduction 61
6.7.2 Changes in primary production 62
6.7.3 Changes in vegetation structure 63
6.7.4 Changes in plant species distributions 70
6.7.5 Remobilisation of sand dunes 71
6.8 Changes in distribution and abundance of key species 72
6.8.1 Common savanna (plains) species 74
6.8.2 Woodland species 77
6.8.3 Flagship species 79
6.8.4 Predators and scavengers 82
6.8.5 Wetland species 84
6.8.6 Endemic species 87

6.9 IMPACTS ON PESTS AND PATHOGENS 90

7 IMPACTS ON LAND USE AND LIVELIHOODS AND THE BIODIVERSITY IMPLICATIONS 92

7.1 INTRODUCTION 92
7.2 CROP PRODUCTION 93
7.2.1 Dryland cropping 93
7.2.2 Irrigation cropping 94
7.3 LIVESTOCK FARMING SYSTEMS 95
7.4 WILDLIFE AND TOURISM PRODUCTION SYSTEMS 102
7.5 IMPACTS ON LAND USE 104
7.6 IMPACTS ON LIVELIHOODS AND WELLBEING 105
7.6.1 Impacts on farmers 105
7.7 KNOCK-ON IMPACTS ON BIODIVERSITY AND PROTECTED AREAS 106

8 EXPECTED CHANGES IN TOURISM DEMAND 109

8.1 INTRODUCTION 109
8.2 FACTORS ATTRACTING VISITORS 109
8.3 VALUE FOR MONEY OF PARKS AND CURRENT WTP 110
8.4 MODELLING TOURISM DEMAND 111
8.5 CLIMATE CHANGE IMPACT ON TOURISM 112

9 EXPECTED CHANGES IN ECONOMIC OUTPUT 113

10 ADAPTATION OPTIONS AND THEIR ECONOMIC FEASIBILITY 117

10.1 INTRODUCTION 117
10.2 SPECIFIC OPTIONS FOR REDUCING DIRECT IMPACTS ON BIODIVERSITY 119
10.2.1 Increasing size and connectivity of the conservation network 119
10.2.2 Promotion of activities that reduce bush encroachment 127
10.2.3 Ex-situ conservation 128
10.2.4 Monitoring 129
10.3 SPECIFIC OPTIONS FOR REDUCING INDIRECT IMPACTS ON BIODIVERSITY 131
10.3.1 Increase water supply 132
10.3.2 Reduce water demand 133
10.3.3 Reduce unpredictability in agricultural systems 134
10.3.4 Diversify livelihoods and build capacity 135
10.3.5 Reduce park-neighbour conflicts 135
10.3.6 Improve management of natural resources 136
10.3.7 Address health impacts 136
10.4 IS ADAPTATION WORTHWHILE? AN ASSESSMENT OF COSTS AND BENEFITS 137
10.4.1 Introduction 137
10.4.2 Economic assessment of direct interventions 138
10.5 STRENGTHENING ENVIRONMENTAL INSTITUTIONS AND POLICY 140
10.5.1 The importance of policy response 140
10.5.2 The Policy Context 141
10.5.3 Strengthening institutions and policy 144

11 OPPORTUNITIES FOR GENERATING INCOME THROUGH CARBON PROJECTS 148

11.1 INTRODUCTION 148
11.2 POTENTIAL FOR AFFORESTATION/REFORESTATION PROJECTS 149

11.3 POTENTIAL FOR OTHER PROJECTS 150

12 CONCLUSIONS AND RECOMMENDATIONS 151

12.1 BIOPHYSICAL PREDICTIONS 151
12.2 EXPECTED DIRECT AND INDIRECT IMPACTS ON BIODIVERSITY 151
12.3 OVERALL RECOMMENDATIONS FOR ADAPTING TO CLIMATE CHANGE 152
12.4 MANAGING THE DIRECT IMPACTS OF CLIMATE CHANGE ON WILDLIFE AND PROTECTED AREAS 154
12.5 MANAGING THE INDIRECT IMPACTS OF CLIMATE CHANGE ON WILDLIFE AND PROTECTED AREAS 155
12.6 THE 'BOTTOM LINE' 156

13 APPENDIX I. POLICY, LEGAL AND INSTITUTIONAL CONTEXT 158

13.1 INTRODUCTION 158
13.2 KEY POLICIES AND LAWS RELEVANT TO LAND MANAGEMENT AND CLIMATE CHANGE IN NAMIBIA 158
13.3 AGRICULTURE 159
13.3.1 Assessment of implementation of the agriculture policy cluster 159
13.3.2 Local level empowerment 160
13.3.3 Land productivity 161
13.3.4 Livelihoods 162
13.3.5 Economics 162
13.3.6 Political alignment 163
13.3.7 Conclusions and recommendations 164
13.4 WATER 165
13.4.1 Assessment of implementation of the water policy cluster 165
13.4.2 Conclusions and recommendations 167
13.5 FORESTRY AND WILDLIFE 168
13.5.1 Assessment of implementation of the forestry and wildlife policy cluster 169
13.5.2 Conclusions and recommendations 172
13.6 LAND 173
13.6.1 Assessment of implementation of the land policy cluster 173
13.6.2 Conclusions and recommendations 177
13.7 ENVIRONMENTAL PLANNING SECTOR 178
13.7.1 Assessment of implementation of the environmental planning policy cluster 178
13.7.2 Conclusions and recommendations 179
13.8 COASTAL MANAGEMENT AND FISHERIES SECTOR 180
13.8.1 Defining the coastal zone 180
13.8.2 Land use and Development Planning along the coast 180
13.8.3 Fishing and aquaculture 183
13.8.4 Conclusions and recommendations 186

14 APPENDIX II. POTENTIAL IMPACTS OF CLIMATE CHANGE ON NATURE-BASED TOURISM DEMAND IN NAMIBIA 189

14.1 INTRODUCTION 189
14.2 METHODS 189
14.2.1 Structure of the questionnaire 189
14.2.2 Modelling climate change impacts 191
14.3 RESULTS 192
14.3.1 Visitor numbers, group and trip statistics 192
14.3.2 Factors attracting visitors 193
14.3.3 Value for money of Parks and current WTP 194

14.3.4 Potential impacts of climate change on visitor utility ... 195
14.3.5 Response to best and worst scenarios ... 196
14.3.6 Potential impacts on tourism ... 196
14.4 DISCUSSION ... 198

15 APPENDIX III. ADAPTATION OF THE PROTECTED AREA SYSTEM TO CLIMATE CHANGE: A CONSERVATION PLANNING ANALYSIS ... 200

15.1 INTRODUCTION ... 200
15.2 METHODS ... 201
15.2.1 Data sets ... 201
15.2.2 Conservation Targets ... 203
15.2.3 Planning units ... 205
15.2.4 Protected Area System ... 205
15.2.5 Eco-regions ... 207
15.2.6 Software ... 207
15.2.7 Area Requirement Scenarios ... 208
15.3 RESULTS AND DISCUSSION ... 209
15.3.1 Gap Assessment and Options for creating a fully representative conservation network ... 209
15.3.2 Changes in biodiversity distribution under climate change ... 213
15.3.3 How well does the current conservation network meet targets for future species distribution? 217
15.3.4 How well does the current conservation network maintain current carrying capacity? ... 218
15.4 CONCLUSIONS ... 224

16 APPENDIX IV. SENSITIVITY ANALYSIS FOR ECONOMIC IMPACT ANALYSIS ... 227

17 REFERENCES ... 238

LIST OF ABBREVIATIONS

AAU	Assigned Amount Unit
AIDS	Acquired Immunodeficiency Syndrome
AFOLU	Agriculture, forestry and other land uses
AR	Aforestation / Reforestation
AR4	Fourth Assessment Report (of IPCC)
BCLME	Benguela current and large marine ecosystem
CBD	United Nations Convention on Biological Diversity
CBM	Community Based Management
CBNRM	Community Based Natural Resource Management
CCF	Cheetah Conservation Fund
CCU	Conservation Credit Units
CDM	Clean Development Mechanism
CER	Certified Emissions Reductions
CLRA	Communal Land Reform Act
CLRA	Communal Land Reform Act
CPP	Country Pilot Partnership
DAPP	Development Aid from People to People
DART	Directorate of Agricultural Research and Training, MAWF
DEA	Directorate of Environmental Affairs
DEES	Directorate of Engineering and Extension Services, MAWF
DoF	Directorate of Forestry, MAWF
DPWM	Directorate of Parks and Wildlife Management
DRWS	Directorate of Rural Water Supply
DVS	Directorate of Veterinary Services, MAWF
DWA	Department of Water Affairs, MAWF
EAF	Ecosystems Approach to Fisheries Management
EC	European Commission
ECFSP	Emerging Commercial Farmers Support Programme
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMA	Environmental Management Act
EMU	Emergency Management Unit
FIRM	Forum for Integrated Resource Management
FSRE	Farming Systems Research and Extension
GCM	General Circulation Model
GCS	Global Conservation Standard
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GRN	Government of the Republic of Namibia
HADCM3	
HWCM	Human Wildlife Conflict Management
HIV	Human Immunodeficiency Virus

ICM	Integrated Coastal Management
ICZMP	Integrated Coastal Zone Management Plan
IMSCLUP	Inter-ministerial Standing Committee on Land Use Planning
IPCC	Intergovernmental Panel on Climate Change
ISLM	Integrated Sustainable Land Management
LA	Local Authority
LFCC	Low Forest Cover Country
LLM	Local Level Monitoring
LRAC	Land Reform Advisory Commission
LUEB	Land Use and Environmental Board
LUP	Land Use Planning
M&E	monitoring and evaluation
MAWF	Ministry or Agriculture, Water and Forestry
MDG	Millennium Development Goal
MET	Ministry of Environment and Tourism
MLRR	Ministry of Lands and Resettlement
MFMR	Ministry of Fisheries and Marine Resources (Namibia)
MoH	Ministry of Health
MOHSS	(former) Ministry of Health and Social Services
MPA	Marine Protected Area
MRLGHRD	Ministry of Regional and Local Government and Housing and Rural Development
MRA	Marine Resources Act
MTI	Ministry of Trade and Industry
MWTC	Ministry of Woks, Transport and Communications
NACOMA	Namibia Coastal Management Project
NACSO	Namibian Association of CBNRM Support Organisations
NAPCOD	Namibia's Programme to Combat Desertification
NAU	Namibia Agricultural Union
NCA	Northern Communal Area
NCSA	National Capacity Self-Assessment
NDP	National Development Plan
NGO	Non-Governmental Organisation
NMS	Namibia Meteorological Service
NNF	Namibia Nature Foundation
NNFU	Namibia National Farmers Union
NPAB	Namibia Planning Advisory Board
NPC	National Planning Commission
NTB	Namibia Tourism Board
PA	Protected Area
PAN	Protected Area Network
PP	Primary Production
PU	Planning Unit
NWR	Namibia Wildlife Resorts
PS	Permanent Secretary
RCM	Regional Circulation Model

RDCC	Regional Development Coordination Committee
REDD	Reduced Emissions from Deforestation and Degradation
REMU	Regional Emergency Management Unit
RPRP	Rural Poverty Reduction Programme
SACU	Southern African Customs Union
SADC	Southern African Development Community
SAIEA	Southern African Institute for Environmental Assessment
SDAC	Sustainable Development Advisory Council
SLM	Sustainable Land Management
SME	Small and Medium-sized Enterprise
SPAN	Strengthening the Protected Area Network Project
SST	Sea Surface Temperatures
TA	Traditional Authority
TAR	Third Assessment Report (from IPCC)
TEV	Total Economic Value
Tralac	Trade Law Centre of Southern Africa
UN	United Nations
UNCCD	United Nations Convention on Combating Desertification
UNFCCC	United Nations Framework Convention on Climate Change
WASSP	Water Supply and Sanitation Policy
WPA	Water Point Association
WPC	Water Point Committee
WTTC	World Travel and Tourism Council
VER	Verified / Voluntary Emissions Reductions
y	Year

EXECUTIVE SUMMARY

Introduction

The main objectives of this study were to assess the vulnerability of Namibia's biodiversity and ecosystems to climate change, to assess the economic implications of climate change-ascribed wildlife and biodiversity changes, and to investigate feasible adaptation options, such as improving the effectiveness of the current protected area network in safeguarding wildlife populations and biodiversity under climate change, so that these areas continue to function optimally and be central to socio-economic growth and development in the country.

The study was initially intended to focus on three or four representative parts of Namibia at a local scale. However, because of the course scale and uncertainty of climate change models, the study was conducted at a national scale.

Geography, climate and biodiversity

Namibia falls within Africa's South West Arid Zone, and is the most arid country in Africa south of the Sahara. Rainfall ranges from about 600 mm in the extreme north-east to less than 50 mm in the extreme south and along the coast. About 22% of Namibia's 823 680 km^2 land area is desert, 70% is arid to semi-arid and the remaining 8% is dry sub-humid. Primary production is low throughout the country, and highly dependent upon annual rainfall. There are four terrestrial biomes: the Tree and shrub savanna, Nama Karoo, Namib Desert and Succulent Karoo. Terrestrial diversity of plants and animals is highest in the north-eastern parts of Namibia, because of the higher rainfall and presence of wetlands and forest habitats that are not found elsewhere in the country. Endemism is highest in the central and north-west parts of the country. Perennial rivers only occur on the country's borders and floodplain wetlands are concentrated in the north-east. Pans such as Etosha Pan are important for biodiversity. Several coastal wetlands support impressive numbers of waterbirds, with three being Ramsar sites. The marine ecosystems off Namibia's coast are influenced by the cold Benguela current system, and tend to be species poor and low in endemism, but highly productive. Several islands off the coast of Namibia support important breeding populations of seabirds.

Land use and conservation

The protected areas network covers some 16.6% of the terrestrial area of Namibia. The proclamation of most protected areas in Namibia pre-dated the emergence of biodiversity conservation science. Parks were established in areas that were perceived to have little other value, such as deserts that were unsuitable for farming, as buffer zones between settler farmers and indigenous people, and for the protection of game animals. Of Namibia's 29 vegetation types, 13 have less than 10% of their respective areas protected in national parks. Marine resources are heavily utilised and the first marine protected area was established in 2009, stretching 400km along the coast and 30km offshore, incorporating 10 islands. This will soon be expanded to the entire coastline.

Outside of protected areas, land use is dominated by livestock, and agriculture to a lesser extent. Crop production is limited to the northern and eastern parts of the country where it is marginal to low, and livestock production ranges from marginal in the south and west to moderate in the north and east. In the north, where 60% of the population resides, agriculture comprises small scale mixed livestock and crop farming, and a high proportion of households are also dependent on natural resources for their livelihoods. Agriculture in these areas is marginal. Cattle are farmed mainly in the central-northern areas. Only 40 000 ha in Namibia area is under intensive commercial cropping. This is mainly in the high rainfall Grootfontein-Tsumeb-Otavi triangle, where irrigation is also widely practiced.

The state has created a policy and legislative framework for freehold farms, communal conservancies and community forests to acquire rights over wildlife, trees and non-timber products, and tourism. This policy framework has led to ever increasing areas of land being converted to indigenous biodiversity production systems, including wildlife, tourism and forestry, a significant increase in wildlife numbers and diversity across the country through effective local management and reintroduction. Land adjacent to protected areas is often more profitable under wildlife and tourism than under conventional farming. This has led to a significant reduction in park-neighbour boundary conflicts as neighbours begin to practice compatible land uses. Including private and communal conservation areas, the broader conservation network covers 45% of the country or approximately 37 million ha, although the 60% under private or communal tenure cannot be assumed to be as efficient as protected areas in their conservation outcome.

In 2005, a “Parks Vision” was developed, which was to effectively expand, manage and develop the park network of Namibia in order to adequately protect the biodiversity and landscapes of the country. This included improving the connectivity of the parks system through establishing new conservancies. The Ministry of Environment and Tourism, which has the mandate for the management of the protected areas system, has recently developed a strategy which is largely aligned with this vision. However it is important to note that the Parks Vision did not take the potential impacts of climate change into account.

The value of land and natural resources

While the focus of this study is on biodiversity protection and the protected area system, in order to understand the potential implications of climate change and adaptation measures it was necessary to have a broad understanding of land uses and their values both within and outside of the protected area system. Values of land and natural resources include those generated by direct uses such as agricultural production, natural resource harvesting and tourism, indirect uses, being derived from the services provided by ecosystem functions, and non-use values, being the welfare value associated with people’s appreciation of the existence of biodiversity.

Agricultural production generates some N$3.23 billion in terms of value added to national income. Some 77% of this is attributable to livestock. Commercial land contributes 74% of total agricultural land use production value, and 79% of livestock production value.

Tourism is a rapidly growing sector in Namibia and the leisure tourism component of this, which makes up some 40% of value, is dominated by nature-based pursuits. The nature-based component is attributable mainly to scenery and wildlife. Nature-based tourism generates some N$2.45 billion in expenditure (leading to an estimated direct contribution of N$1113 million or 2.1% of GNP), of which about N$433 million is spent in state protected areas.

Tourism, wildlife, and natural resource uses were estimated to be worth some N$3.8 billion in 2009. This is dominated by two main components; tourism (47%) and natural plant use (44%). Currently 70% of tourism value is generated on freehold land. There remains significant potential for tourism development within parks and communal areas.

Climate change predictions

It is predicted with a high degree of certainty that Namibia (and the rest of southern Africa) can expect an increase in temperature and evapo-transpiration at all localities, with the maximum increase (2 - 6°C) in the interior. Warming is likely to be less along the coast than along the escarpment and inland regions (though the levels of uncertainty are high regarding currents, winds, sea temperatures and fog). Most global circulation models and the median of these models project that Namibia will become drier, rainfall variability is likely to increase and extreme events such as droughts and floods are likely to become more frequent and intense. Soil moisture levels are projected to decline, with the cumulative impacts of higher temperature, lower rainfall, higher run-off, lower humidity, higher evaporation and lower plant cover probably creating a compounding impact on soil moisture and on primary production that is greater than the sum of their individual contributions. There are currently no credible projections of changes to Namibia's coastal fog system, which is known to be vital for most endemic and many other plant and animal species in the Namib.

For this analysis it was assumed that a 10% decrease in rainfall will be experienced in the northern and southern regions of Namibia, and a 20% decrease in the central regions, by 2050, and that these figures will worsen to 20% and 30% respectively by 2080.

Direct Impacts on ecosystems and biodiversity

Coastal areas are likely to see increased incidence of flooding and inundation, affecting low-lying urban areas. Marine species most sensitive to climate change will be those that have been heavily exploited.

Wetlands (including coastal lagoons and seasonal oshanas), and their associated fauna and flora, are among Namibia's most threatened ecosystems. Most are underprotected and highly vulnerable to increasing pollution, water abstraction and devegetation. The impacts of climate change on wetland systems are difficult to predict as insufficient work has been done to derive any clear projections. The Orange River is heavily regulated and future flows in this system are likely to be determined primarily by the socio-economic needs of South Africa rather than climate change. Namibia's northern rivers may experience an increase in water volumes and flooding may be more frequent and of greater magnitude. While this will have initial negative consequences for people it will have positive ecological impacts. It will favour resident wetland and floodplain species such as Hippopotamus, Sitatunga, Lechwe, Reedbuck, Puku, otters, Crocodile, wetland birds such as Fish Eagle, Wattled Crane, ducks, storks and many others, as well as fish, mollusks and other aquatic invertebrates. It will have positive impacts on fish recruitment and production, for both subsistence and tourism.

Namibia's ephemeral wetland systems have their catchments within Namibia and will be subject to decreasing rainfall and increasing temperatures and rates of evaporation, which will probably result in less frequent and lower magnitude flooding. This will reduce aquifer recharge and result in a lowering of the water table. The implications for biodiversity could be severe as large trees in riverbeds provide essential fodder and habitat to many species of wildlife.

There are five Ramsar wetlands in Namibia and it is likely that the inland sites will receive less water inflow. Reduced inflows into the Etosha pan may impact on the natural springs around the southern parts of the pan and on the breeding of Greater and Lesser Flamingos. The only other breeding area for these flagship species in southern Africa is the Makgadikgadi Pan in Botswana, which will probably experience similar drying conditions to those in Etosha.

Terrestrial areas that are particularly vulnerable to climate change include the western escarpment (which separates the arid desert from the semi-arid savannas), and the south-western Succulent Karoo – both important centres of endemism. The latter is considered to be one of the world's 25 top 'global biodiversity hotspots' and is likely to suffer considerable numbers of local extinctions by 2050. Namibia's vegetation is likely to shift in spatial dominance from Grassy Savanna to Desert and Arid Shrubland by 2080 and ground cover will decline throughout much of the country. A sustained increase in ambient temperature is capable of causing significant changes in species distribution, composition and migration. The south and south west parts of the country are predicted to see the greatest increase in total plant species numbers as well as the lowest proportion of species loss, whereas much greater losses are expected to be experienced in the central, northern and eastern areas. Some 7% of plant species have been estimated to shift their distribution range out of Namibia entirely with 52% of species showing range contractions and 41% showing range expansions.

The semi-arid to arid plains game of Namibia are largely climate tolerant, with small expansions of range expected in some species towards the north-east in response to an expected shift of the savanna biome, and small declines expected in the ranges of some species in the extreme west and south as the hyper arid Namib expands. Springbok and Gemsbok will likely expand their ranges to the BwaBwata National Park but none of the ranges of plains game species are likely to retreat out of any of the national parks. If parks are managed as isolated units and fenced, then the numbers of plains game will decline because the overall carrying capacity will decline. This will be particularly severe in the most arid regions, e.g. Namib-Naukluft Park and Sperrgebiet National Park, where wildlife numbers may crash to very low levels following periods of prolonged drought. The most important adaptation by plains game to arid savanna systems is their mobility – migratory and nomadic responses to variable and unpredictable rainfall, both temporally and spatially. It is thus essential to maintain open systems and manage across large landscapes. This can be achieved by implementing park-neighbour initiatives that create co-managed open landscapes.

Woodland ungulates are sensitive to climate change and will likely retreat to the north-east. They are not expected to prosper in the Etosha and Waterberg Parks, and MET should focus its conservation efforts for these species on the Khaudum, BwaBwata and Mudumu Parks. Open systems should be maintained with neighbouring areas which are under compatible forms of land use, both within Namibia and across international borders, particularly with Botswana. Where populations of these species are held below about 400 mm mean annual rainfall, supplementary feeding will be required in dry times. Because of their high value, this may be a viable economic option for wildlife production systems, but inappropriate for national parks.

Namibia's two subspecies of impala (Common and Black-faced) are important production animals as they reproduce rapidly, provide excellent meat and are attractive for tourism and trophy hunting. They are also fairly resilient to climate variability because of their broad diet. Their ranges are not expected to change significantly as a result of climate change, perhaps retreating slightly to the east in both cases. An opportunity may exist for expanding the range of Black-faced Impala into the Otavi Mountains, but all Common Impala must be removed from the area prior to reintroductions to avoid hybridization.

Flagship species such as Elephant, Rhino, Giraffe, Hartmann's Mountain Zebra, predators, cranes and vultures are highlighted in this study because of their importance for, inter alia, conservation, their representation of cohorts under pressure (e.g. species with high value by-products, scavenging species, wetland species) and tourism.

Elephants are able to survive in a wide range of habitats, even extending along dry river courses into the Namib Desert. However, declining rainfall and carrying capacity will lead to Elephants exerting extra pressure on these habitats. Active Elephant management is needed to prevent habitat damage, biodiversity loss and human-wildlife conflicts. Elephants currently occupy a very small part of their former range because of high human density and conflicting land uses. However, as more land is placed under wildlife management and as co-managed landscape approaches are adopted over large areas, so will Elephant range and numbers increase, because they make an economically significant contribution to wildlife production systems, through various forms of utilization, particularly tourism.

Giraffe also survive in a wide range of habitats across Namibia and into the edge of the Namib Desert where ephemeral rivers and drainage lines provide suitable habitat. Their range is not expected to change significantly, though their density may decrease in some areas with declining woody vegetation, their overall numbers may increase because of growth in the wildlife sector and more land coming into wildlife production.

Black Rhino are browsers able to tolerate more arid conditions than the White Rhino, which is a grazer. The range of the Black Rhino is not expected to change, though a decline in carrying capacity may result in Etosha National Park and parts of the Kunene Region, which may be overpopulated. Animals should be removed from these high density areas and used to start new populations in areas that have the potential to support significant meta-populations, e.g. in Khaudum and Ai-Ais National Parks, Nyae-Nyae and N≠a_Jaqna conservancies. By contrast, the range of White Rhino in Namibia is expected to retreat from the west and south and to expand to the north-east, where the Khaudum and BwaBwata National Parks will likely provide suitable habitat by 2050. The prediction that grasslands will prosper at the expense of woodlands in north-eastern Namibia would further favour White Rhino. The establishment of new White Rhino populations west of Windhoek and south of Mariental should be discouraged.

Hartmann's Mountain Zebra is a near endemic subspecies. It is highly nomadic, showing clear west-east movements patterns. Being arid adapted its range is not expected to change significantly as a result of climate change, though populations may adjust to declining carrying capacity. It is important that a park-neighbour and co-managed landscape approach is implemented to allow this species to move over large areas. If this is achieved, its populations will be secure despite the impacts of climate change. It is also worth exploring the introduction of this species to the Otavi mountain range as conditions there get drier.

Predators and scavengers are largely climate tolerant. If their food source is secure their distribution and abundance will be little affected. Protected areas and land under wildlife and tourism are vital for their long-term survival because these animals are heavily persecuted in livestock production areas. A shift towards small-stock will increase the risk to predators and scavengers. An ongoing shift towards wildlife-based land uses, especially tourism, and the establishment of large open co-managed systems will, however, lead to the recovery of predators and scavengers.

Namibia's endemic plants and animals occur mainly along the western escarpment with the belt of greatest endemic diversity being east of the coastal national parks and west of Etosha National Park; and south of eastern Etosha via Windhoek to the Naukluft Mountains and into the Sperrgebiet. This belt does not extend significantly into the national parks network, but occurs on communal lands mainly in the Kunene and Erongo regions, and on freehold land in mainly the Otjozondjupa, Khomas and Erongo regions. Much of this land falls within communal and freehold conservancies, which highlights the importance of creating appropriate incentives and encouraging the custodians of these areas to manage them in appropriate ways.

It is expected that climate change impacts on ground living endemic animals on the escarpment belt and central highlands is likely to be limited. Numbers may decline slightly and the ranges of some species may expand somewhat to the east for those species whose eastern limits are determined by rainfall. The western limits of these escarpment species are unlikely to change. The abundance of arboreal species may decline with the predicted decline in woody plants of less than 2 m tall. The status of Namib endemics not dependent on coastal fog is also unlikely to change significantly. However, the status of endemics and other species that do rely on coastal fog may be at significant risk. There are currently no credible projections on likely changes in coastal fog as a result of climate change. If fog were to decline in frequency, moisture levels and eastward extent, very significant changes in the status of endemic and other species would occur. Such changes would put many species at risk of extinction. It is therefore a priority to try and understand what impacts climate change may have on coastal fog and associated biodiversity.

Changes in land and resource use and the socioeconomic and biodiversity implications

Namibia's farming systems are on the arid margins of viability. The impacts of projected climate change on these production systems are expected to be severe. This in turn will have significant impact of the livelihoods of rural households as well as on the economy of farming-related businesses. The resulting anthropogenic impact on Namibia's indigenous biodiversity is expected to exceed the direct impacts of climate change on biodiversity.

By 2050 it is likely that only the eastern Kavango and Caprivi will be able to produce crops under rain-fed conditions. Even the food growing Grootfontein-Tsumeb-Otavi triangle is on the very margins of economically viable rain-fed crop production, and it is predicted that the failure rate of crops will increase, resulting in a shift to small-scale irrigation that requires significant abstraction of ground water. In terms of commercial crop irrigation, it is expected that:-

- Inter-annual variability of net irrigation water requirements will increase;
- Virtually all irrigated lands will require at least 10% more water applications per annum. Irrigated land in Lesotho may require up to 30% more irrigation applications per year – impacting considerably on the downstream end of the Orange river;
- The leaching of pesticides and fertilizers from irrigated land will cause an increase in water pollution – threatening freshwater ecosystems and human health;
- The growing season of maize may shift to an earlier date and, as a result of increased temperatures, shorter growing seasons and reduced yield quality are likely; and
- Weeds and crop pests will increase.

These trends will also lead to a greater focus on livestock. However, livestock production will also suffer. In terms of livestock farming, Namibia's long-term carrying capacity is already exceeded in many places. The productive area for large stock in Namibia will shrink towards the east and north and cattle will decline significantly and probably be replaced by small stock and more profitably by wildlife and tourism in many areas. The amount of land that will remain viable for farming in general will decline from the present 64 million ha to 57 million ha in 2050 and 53 million ha in 2080; a decline of 11% and 18% respectively. The situation for small stock farming is similar to that of cattle farming, and the same carrying capacity principles apply. The productive area for small stock in Namibia will retreat from the west and expand towards the north and east into former cattle farming areas. Despite an overall increase in productive range the numbers of small stock are predicted to decline by 16% and 25% by 2050 and 2080 respectively. By comparison, cattle numbers are predicted to decline by 24% and 49% respectively. A mean loss of 28% of livestock revenue can be expected by 2050. Cattle will probably be replaced by small stock and more profitably by wildlife and tourism.

Impacts on wildlife are expected to be less severe than on agricultural production. Changes in carrying capacity are predicted to lead to declines in wildlife in protected areas of about 12% by 2050 and 25% by 2080. Similar declines of 11% and 22% are predicted for communal areas, and 13% and 24% for freehold areas. At the national level, a decline of 13% by 2005 and 24% by 2080 are predicted. This is likely to encourage further shifts in land use from agriculture to wildlife.

Unless concerted, innovative and effective interventions are pro-actively applied, the socio-economic implications of climate change on the farming sector, on the rural population and on the supporting businesses and services are likely to be severe. In the worst affected communal land areas, the predicted changes will lead to increases in poverty and vulnerability, debt and lawlessness, as well as to an increase in dependence on natural resources and government assistance. These in turn will have significant implications for the environment, for biodiversity and for Namibia's protected areas. The indirect impacts on Namibia's environment, resulting from climate change impacts on farming systems, holds a far greater threat to Namibia's indigenous biodiversity and its protected areas than do the direct impacts of climate change.

Impacts on tourism demand

A survey was conducted to determine factors affecting the demand for wildlife tourism by assessing their response to various climate change scenarios. Holiday makers were interviewed in Namibian National Parks and at Hosea Kutako International Airport in Windhoek, during June – July 2009. The study showed that tourism would be relatively resilient to losses in biodiversity because of the high contribution of landscapes to the visitor experience, and the fact that these would not be significantly impacted by climate change. Without any change in tourism strategy, predicted changes in biodiversity could reduce nature-based tourism demand by up to 15%.

Impacts on economic output

Estimated economic losses were highest for the livestock sector (N$2 035m), and in particular for commercial fenced ranching. This is a result of the fragile financial and economic viability of this system, where a small drop in income results in a devastating loss in net income. In terms of long term adaptation it means that medium to large scale livestock farming systems will tend towards becoming lower input in nature, with systems closer to the cattle posts of the communal lands rather than ranches. Dryland cropping will be almost eliminated but this will be compensated by irrigated crop production in which a lot of resources will be expended despite scarcity of water and poor financial viability. Losses in this sector are predicted to be in the order of N$137m. Income from natural resources use is expected to be more resilient in the face of climate change, given the generally lower reliance of these activities on primary production and rangeland carrying capacity, with total losses of about N$327m. In total climate change is estimated to reduce land-based economic outputs by a total of just under N$2.5 billion per annum (in 2009 values) by 2080. This does not include other costs such as those associated with deterioration in social systems and health.

Adaptation options and their economic feasibility

Adaptations options were examined in terms of addressing both direct and indirect impacts on biodiversity as a result of climate change. Among options to address direct impacts, the most important is addressing the coverage of the conservation network (including state, private and communal conservation areas). As a proportion of the country, Namibia probably has one of the largest conservation networks of any country globally. Only 2% of biodiversity features targeted are not represented within the conservation network at all, and a total of 5% fall short of their target. Thus, the Namibian conservation network is currently representative of the majority of the country's biodiversity, but there are some notable gaps:

- The Cuvelai drainage ecosystem has been almost entirely transformed and is the only "critically endangered" landscape in Namibia.

- The south of the country especially the SE (Nama Karoo and Orange River valley) is the most poorly represented in the conservation network and consequently the area where most outstanding targets are still to be met.

A conservation planning analysis was conducted, in which conservation targets were set at an area equivalent to 10% of the *future* predicted range of each species. The current conservation network is also effective at achieving future targets for plant species (99%). Mopping-up outstanding future species targets would require a 20-30% expansion of the conservation network. Maintaining current populations would require an estimated 35-43% increase in the size of the current conservation network. Most of this expansion could be achieved by expanding and consolidating existing PAs with notable exceptions in the south of the country particularly the southern Kalahari where there are currently no protected areas, and where there is opportunity to extend the Kgalagadi Transfrontier Conservation Area.

The following conservation measures are recommended:

- Addressing gaps in the conservation network by
  - Expansion and consolidation of conservation areas particularly in the north.
  - Creation of conservation areas particularly in the SE Kalahari, Nama Karoo and eastern Orange River valley regions.
- Promote persistent populations by removing fencing to create larger contiguous management areas that meet viable animal population size requirements and facilitate species movement in response to seasonal variation.
- Conservation efforts for woodland ungulate species which will no longer prosper in Etosha should be focused on the Khaudum, BwaBwata and Mudumu Parks.
- Facilitate species movement through building a landscape-level biodiversity corridor network that will allow biodiversity to respond to changing climates. Consolidating the existing conservation network into 3 major bioregional corridors would contribute significantly to the maintenance of macro-ecological climatic gradient corridors. These corridors are the:
  - North-south escarpment/Namib corridor (existing)
  - West-east Kaokoveld-Caprivi corridor (existing)
  - West-east southern Namib-Kalahari corridor (not existing)
- Cooperate with neighbouring states when planning and implementing landscape-scale corridors to align conservation management efforts across political boundaries.
- Adopt integrated river basin management and develop a national policy and action plan that safeguards wetland ecosystems. The Eastern Zambezi-Chobe River and floodplains, the Kwandu-Linyanti system, the lower Kavango River in Namibia and the Nyae-Nyae Pan system should be considered as potential Ramsar sites.
- Maintain an ecosystem approach to fisheries management.

In terrestrial areas, increased conservation can be achieved through voluntary actions by landowners, which can be stimulated by focussed CBNRM support, active promotion of nature based tourism and general preparation for major shift in land use to wildlife tourism. Preserving species in artificial environments (e.g. zoos) should be regarded as a last resort.

Bush encroachment will have to be addressed through encouragement of production of charcoal and fuel wood, and possibly small-scale power generation.

A properly-designed monitoring program will allow biodiversity trends and status within the protected area network to be assessed. The rational for monitoring is that it allows a clear trend to be established which can be correlated with climate data to give an understanding of the impacts of climate change. Key requirements of a monitoring program would be to establish an inventory of flora and fauna within the protected are network.

Options for reducing indirect impacts of climate change on parks and wildlife involve reducing impacts on agriculture and livelihoods. One of the most important needs for adaptation will be within the water sector. This should involve the adoption of Integrated Water Resource Management, including measures to increase water supply and reduce demand. Measures to improve water supply could include inter-basin transfers, rehabilitating water basins, artificial recharge, desalination and appropriate water harvesting systems. Water demand should be addressed through water saving technologies, drought resistant crops, and indigenous technologies.

Pressures arising as a result of reduced agricultural productivity should be addressed through measures such as diversifying livelihoods, including building capacity in this regard. Unpredictability in agricultural systems will need to be addressed though a move to more robust practices. Natural resource shortages will need to be addressed with improved natural resource management. The new human Wildlife Conflict Management Policy and the Policy on Parks, Neighbours and Resident People will help to deal with the park-neighbour conflicts that are expected to arise. Health impacts can be addressed both by improving public health infrastructure, and by maintaining biodiversity and predator-prey interactions, and avoiding monoculture.

The high levels of climate variability and current lack of reliable data result in a very restricted predictive capacity of the climate models creates difficulties in attempting economic analysis of climate change adaptation required for the protected area network. The climate-change impacts described in this report would take place over seventy years, and would be mitigated to some extent by autonomous adaptation. In other words, some of the measures we envisage would take place gradually without any intervention. Nevertheless, losses will be felt, particularly in the agricultural sector, and active intervention would need to be made to accelerate and better direct the required adaptation measures. This means increasing the focus on rangeland and natural resource management, and shifts into conservation-oriented business, and would involve building on existing programmes such as CBNRM. Given the relative advantage of wildlife in marginal agricultural areas, these interventions are likely to have a positive return, with a base case economic rate of return (ERR) of some 20%, even though the full climate change impacts may not be felt for many years to come. The results of this analysis suggest that adaptation can be carried out in an economically efficient manner. In the case of the CBNRM activities, the benefits are anticipated to be greater than just the offsetting of potential losses due to climate change.

Opportunities for income from carbon projects

Financing will need to be found for some of these measures. While Namibia is unlikely to be able to generate significant revenue from afforestation/reforestation-type carbon projects, opportunities for other types of carbon projects, such as concentrated solar power and small-scale biomass energy production, are worth exploring. Meanwhile, Namibia should also apply for adaptation funding in order to meet some of the challenges that lie ahead.

Policy recommendations

Environmental institutions and policies focused on the agriculture, water, forestry and wildlife, environmental planning, coastal management and fisheries will need to be strengthened in order to make them more resilient to climate change. These will need to be robust, promoting best practise and preparedness across all sectors.

Namibia already has to deal with severe environmental conditions of poor soils, low and highly variable rainfall, high temperatures, high rates of evaporation and meagre amounts of fresh water. Addressing the challenges of climate change through appropriate adaptation will automatically improve current management practices, enhance sustainability and promote socio-economic development. The converse is also true – that is, better management of the current situation is a pre-adaptation for coping with climate change. Many of the elements required for both improved current management and climate change adaptation are already contained in Namibia's Vision 2030, but have not been put into full effect. The first is to recognise Namibia's strategic comparative and competitive advantages. The second is to strengthen the policy environment to create incentives for the growth of businesses and enterprises around these. The third is the create and nurture strong and full partnerships between government and civil society (business sector, community sector, NGOs and academic institution) with none curtailing the other, with minimal bureaucracy, with maximum collaboration and working to optimize outcomes. And the fourth is to work to identify key bottlenecks and to remove these, so that sustainable socio-economic development is effectively unleashed.

Thus, Namibia's ability to adapt requires appropriate policies and laws, functioning institutions and partnerships, consistency in decision making, educated and competent citizens, access to technology and the appropriate allocation of resources, all of which combined with ensure wealth creation. In the future as in the past, the success of adaptation to climate will require choosing the right development options, so that those who are vulnerable (inevitably the poor) are not exposed to greater climate risk, and so that environmental integrity is maintained.

1 INTRODUCTION

1.1 BACKGROUND

Namibia's biodiversity enjoys a level of protection which is very high relative to most other parts of Africa. However, it is increasingly threatened by the country's growing population, which is predicted to reach 3 million by 2050. Population growth poses a number of challenges, including socio-economic difficulties associated with increased unemployment, rapid urbanization (>5% in some towns), susceptibility to disease epidemics, rising health care and water supply costs, and a reduction in food security. All of these will, in turn, increase pressures on biodiversity, particularly outside of the protected area system, but also within it. Superimposed on these concerns is the growing realization of the potential way in which climate change will exacerbate these effects. As our understanding of the biophysical implications of climate change begins to crystallize, so does the realization that countries will need to choose a course of action in response to the anticipated effects. Thus it is imperative that countries examine their vulnerability to climate change, and assesses what kind of adaptation should be implemented in order to minimize the negative effects that it might have. Given its increasingly recognized importance in sustaining socio-economic systems, such assessments need to focus on biodiversity as well as more conventional sectors. This is particularly true in Namibia, where wildlife and tourism are crucial to the country's small economy, and it is expected that the role of this sector will become relatively more important in the decades ahead. However, as with all sectors, wildlife and tourism are potentially vulnerable to climate changes and the anthropogenically-induced pressures that will go with it. Recognising this, this study was commissioned by the UNDP in conjunction with Namibia's Ministry of Environment and Tourism.

1.2 OBJECTIVES OF THE STUDY

The main objectives of this study were to assess the vulnerability of Namibia's biodiversity and ecosystems to climate change, to assess the economic implications of climate change-ascribed wildlife and biodiversity changes, and to investigate feasible adaptation options, such as improving the effectiveness of the current protected area network in safeguarding wildlife populations and biodiversity under climate change, so that these areas continue to function optimally and be central to socio-economic growth and development in the country.

1.3 STUDY AREA AND SCOPE OF THE STUDY

The TORs required the consultants to focus on specific focal areas representing different types of landscapes in Namibia. Following initial discussions, the four areas originally envisaged by the client, were grouped into three areas, as follows (Figure 1.1):

- North-eastern Namibia, incorporating the BwaBwata – Mudumu – Mamili Parks complex, including Mahango Game Reserve (wetland habitats);
- North-western and north-central Namibia, including the Skeleton Coast Park (arid coastal desert), the escarpment and Etosha National Park (savanna and woodland habitats)
- South-western Namibia, incorporating the Sperrgebiet (arid, winter-rainfall area).

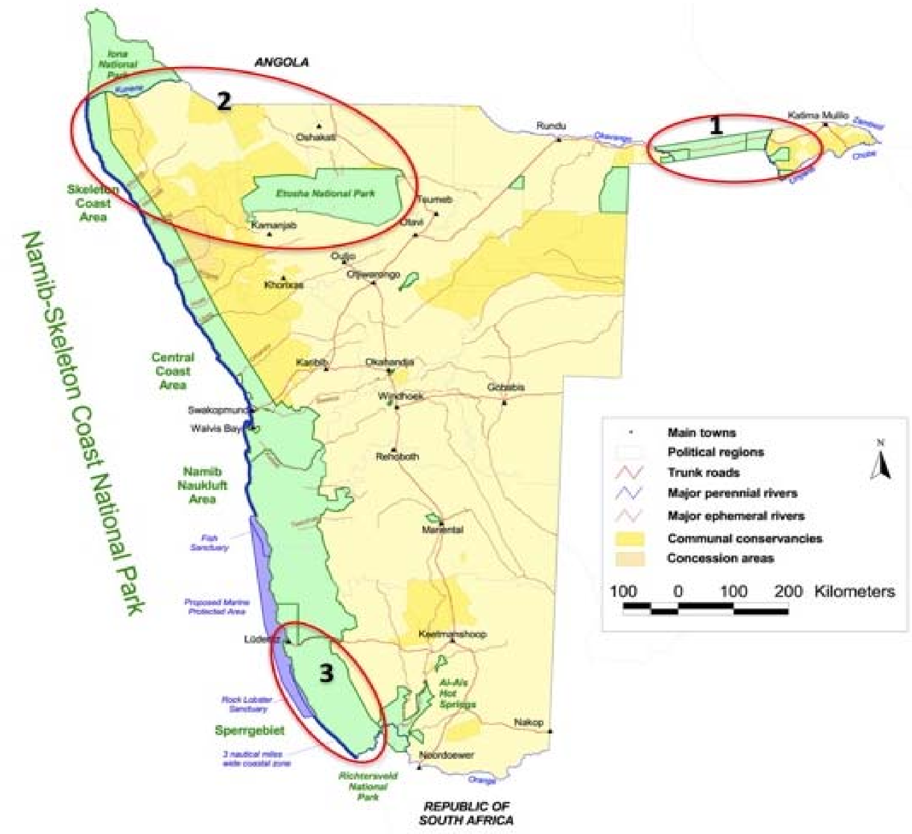


FIGURE 1.1. MAP OF NAMIBIA, SHOWING PROTECTED AREAS AND (IN RED CIRCLES) THE THREE FOCAL AREAS ORIGINALLY IDENTIFIED FOR THE STUDY.

However, as the work progressed it became clear that climate change predictions are highly uncertain, are generated at an extremely coarse scale and are not designed for local-level analysis. Since excessive focus on small areas can generate a false sense of accuracy, it was agreed with the Client that the study consider Namibia as a whole rather than the three focus areas. Moreover, a country-wide analysis is more representative of the overall conservation system – incorporating conservation and wildlife activities outside of protected areas as well as the protected areas themselves.

The specific tasks identified in the terms of reference of the study were as follows:

- Summarise existing literature and known information with regard to climate change projections in protected areas and in Namibia
- Identify information and knowledge gaps in Namibia in relation to climate change and climate change in protected areas
- Identify the impacts and risks of climate change to these ecosystems, i.e. species extinction, fire, weed spread, increased drought or flooding
- Identify the degree/extent that these impacts and risks may have on the ecosystem in the short, medium and long term
- Conduct a sensitivity analysis of wildlife, flora and fauna, habitats and water resources to different level so climate change risk using the best fitting global climate change models and estimate in quantitative terms what this will mean for a) land productivity in terms of ecosystem integrity and b) game productivity
- Highlight the potential ecological impact of these factors on the protected area i.e. species extinction
- Identify the social and economic costs of these changes on the protected area system including loss of economic benefits associated with PA tourism
- Assess social and economic costs of 1. Failure to adapt (the default situation) and 2, adaptation options
- Identify methods and interventions for how the impacts and risk of climate change can be avoided, remedied or mitigated, including the ecological, social and economic value of these interventions
- Identify indicators of and methods for measuring the extent of climate change impact on Namibia's protected areas
- Quantify the existing carbon sequestration (millions of tonnes of CO_2) that results from each case study site and all protected areas in Namibia
- Identify the opportunities for protected areas to sequester or offset further carbon emissions and obtain revenue from such activities
- Provide recommendations about the interventions, procedures and institutional arrangements required for climate change considerations, including adaptations measures so that they are further enhanced and accounted for in protected area policies and management.

1.4 LIMITATIONS OF THE STUDY

The budget and programme precluded the conducting of original field observations other than the tourism survey. Thus, the team relied on available literature and expert input. The paucity of long term climatological and biodiversity data for Namibia is a major constraint for work of this nature.

2 GEOGRAPHY, CLIMATE AND BIODIVERSITY

2.1 Geography and climate of Namibia

Namibia is a large country of 823 680 km^2 on the Atlantic coast of southern Africa located between approximately 17^o and 29^o South and 11^o and 26^o East. Namibia's landscapes are defined largely by a combination of characteristics of topography, geological processes and drainage. In the north, south-central and southern areas a steep escarpment runs north-south and divides the country into low-lying coastal plains about 70-100 km wide to the west and a higher inland plateau to the east. The hilly and mountainous plateau gives way in the east and north to a flat Kalahari sandveld, sloping gently to the east and south, and blown into dunes in some areas. Inselbergs lie scattered throughout the central and western areas, the granitic Brandberg rising from the coastal plains to 2579 m above sea level, the highest point in Namibia. Namibia has just four perennial river systems, all confined to its borders, three in the north (Kunene, Okavango and the Kwandu-Linyanti-Chobe-Zambezi Rivers) and one in the south (Orange River). All other drainage systems within Namibia are ephemeral. The Cuvelai drainage system entering northern Namibia from Angola carries water into the Etosha Pan, the largest salt pan in Namibia that extends about 130 km east-west at its widest point by about 50 km north-south. Twelve small islands lie close to the shore between Walvis Bay and the Orange River on the South African border.

Namibia is characterized by four desert systems, the Namib, which runs along the entire west coast from the port town of Luderitz at 26.7^o S, northwards into southern Angola; the Succulent Karoo which lies south of Luderitz and extends across the Orange River into South Africa; the Nama Karoo which occurs immediately to the east of the previous two desert systems and covers most of the southern third of Namibia, tapering to a narrow belt from central Namibia northwards; and the Southern Kalahari which extends eastwards across to Botswana.

With a human population of about 2.1 million people, Namibia has one of the lowest population densities in the world, on average about 2.5 people per km^2. The population is unevenly distributed with about 35% living in towns and villages. Of the rural population, some 53% live in the Cuvelai drainage system north of Etosha, within a five km belt along the Okavango River and within five km of the Caprivi floodplain system. This area covers just over 6% of Namibia, and has sufficient water and rainfall to support marginal agriculture. Most of the rest of the country has less than 1 person per km^2. Windhoek is the capital city, located near the centre of the country with a population approaching 300 000 people. About 39% of Namibians are under the age of 15.

Namibia is the most arid country in Africa south of the Sahara. Namibia's climate is driven by three major climate systems, the Inter-Tropical Convergence Zone, the Subtropical High Pressure Zone and the Temperate Zone. The Inter-Tropical Convergence zone feeds in moist air from the north while the Subtropical High Pressure zone pushes the moist air back with dry cold air. The latter normally dominates, leading to an absence of water in the atmosphere and giving Namibia its arid climate. The lack of moisture in the air also results in intense radiation from the sun, high daytime temperatures, high evaporation rates, low soil moisture and rapid temperature loss at night.

Namibia's rainfall ranges from about 600 mm in the extreme north-east to less than 50 mm in the extreme south and along the coast (Mendelsohn *et al.* 2002). Central- to north-western Namibia experiences one of the steepest rainfall gradients anywhere in the world, ranging from about 400 mm to less than 50 mm over a distance of just 230 km. Rainfall is highly erratic and unpredictable with an inter-annual coefficient of variation that ranges from about 30% in the north-east to over 100% in the driest areas. Another way of looking at the variation is to assume that 13 in every 14 years are "normal" while one year in the sequence is abnormally dry. Running a transect from south to north and then east, the mean and average driest "normal" years would look as follows: Keetmanshoop 120 mm and 30 mm, Mariental 200 mm and 70 mm, Windhoek 380 mm and 150 mm, Otjiwarongo 420 mm and 230 mm, Tsumeb 500 mm and 280 mm, Katima Mulilo 620 mm and 360 mm. For most of Namibia rain falls in the summer months of November to March but the Succulent Karroo in the south west receives a significant amount of its meagre rainfall in the winter months of June to August.

About 22% of Namibia's land is classified as desert (hyper-arid), 70% is classified as arid to semi-arid and the remaining 8% is classed as dry sub-humid (Mendelsohn *et al.* 2002). Most of the country receives an annual average of more than nine hours of sunlight per day. The north and south of the country experience the highest temperatures with the average maximum for the hottest month being over 34^{o}. The Southern Kalahari experiences the lowest temperatures with the average minimum for the coldest month being less than 2^{o}. Temperature data for Windhoek is available from about 1910. The five year running average of the annual average temperatures from 1920 to 1940 declines slightly from about 19.5^{o} to 18.5^{o} then rises to about 20^{o} by 1970 and 21^{o} by 2000. The four hottest years occur after 1997. This trend is mirrored by the annual average winter temperatures.

All of Namibia, except for the coastal plains, experiences humidity of below 30% during the day for much of the year - in the north-east for about six months, the north-centre for seven months, the central area for eight months and in the south for all 12 months. High temperatures and low humidity result in high rates of evaporation. Evaporation rates from an open body of water inland of the coastal plains range from about 2000 mm to over 2660 mm per annum.

The climate of the coastal belt to the escarpment differs from the rest of Namibia and is influenced mainly by the cold Benguela Current and the South Atlantic Anticyclone. The cold waters of the Benguela Current cool the air so much that it cannot rise up and develop into large rain-bearing clouds. The sea air remains trapped in a layer from the sea to about 600 m above sea level. Moisture from the sea is seen only as low clouds and fog. Moist tropical air from the east and north has usually shed its moisture before reaching the Namib coastal areas. And even when rain-bearing clouds do approach, they are usually blocked by breezes from the sea which blow inland for some distance, often to the escarpment. And finally, any moist tropical air blowing towards the desert descends over the escarpment, warming and drying out as it sinks down. These factors all combine to make rainfall an unusual event on the coastal plain. Temperatures are generally moderate (average minimum and maximum temperatures during the coldest and hottest months respectively reflecting a range of about 7-32^{o}C), fog is frequent (about 125 days per year on the coast dropping to about 40 days per year 80 km inland) and wind is a dominant feature. The southern part of the coast is a particularly high wind energy area, especially in the summer months with average daily speeds of over 40 km/h. These winds are mainly from the south and drive the Benguela Current northwards, carry sand from the shore into the adjacent land, particularly into the southern dune fields, and cause upwelling events along the coast which bring nutrient-rich water to the surfaces.

Namibia's climate has been arid for millions of years. As a result, the soils are generally poor. Soil quality depends on four main attributes, its moisture, depth, structure and nutrient content. The country can be divided broadly into two zones, soils derived from rocky areas in the south, central and much of the western regions, and the Kalahari wind-blown sands that dominate the eastern and northern regions. In the rocky areas the soils are usually shallow and much of the rainwater is rapidly lost from surface flow. Only some 2% is estimated to enter the groundwater. The Kalahari sands are extremely low in nutrients and, because water drains easily through the sand, little moisture is held by the surface layers where most plants have their roots. The combination of poor soils and low rainfall means that primary production is low throughout the country, and highly dependent upon annual rainfall. This is reflected in both crop production, which is limited to the northern and eastern parts of the country where it is marginal to low, and livestock production, which ranges from marginal in the south and west to moderate in the north and east. In the south and west, the long-term stocking rate is in the order of 10-20 kg.ha^{-1}, in the central and northern regions 20-40 kg.ha^{-1} and in the north-east 40-60 kg.ha^{-1} (Mendelsohn 2006).

The marine ecosystems off Namibia's coast are influenced by the Benguela Current System, which extends along the eastern edge of the southern Atlantic Ocean between Cape Agulhas (South Africa) and the Congo River mouth (Angola). The Benguela Current System is one of four major eastern-boundary current systems which are characterised by the wind-driven upwelling of cold, nutrient rich water (Shannon & O'Toole 1998).

The rich supply of nutrients to surface waters provides the ingredients for large phytoplankton blooms, which in turn support a large biomass of fish, seabirds and marine mammals. Consequently the Benguela Current Large Marine Ecosystem (BCLME) is recognised as one of the most productive LMEs in the world (Clark *et al.* 1999). The intensity of upwelling fluctuates seasonally, with variations in wind patterns, and geographically according to the width of the continental shelf such that upwelling is most intense where the wind is strongest and the shelf is narrowest (Sakko 1998). The most intense upwelling along the coast of Namibia occurs within four upwelling cells, the largest and best known of which is the cell just north of Lüderitz. The nutrient rich water, forced up to the surface by this upwelling cell, is distributed northwards by the Benguela current. The high abundance of fish and other marine organisms on and off the Namibian coast is a direct result of this process (Mendelsohn *et al.* 2002).

2.2 Terrestrial biomes, biodiversity and productivity

Namibia's vegetation and biomes are classified into five major types, shown in Figure 2.1.

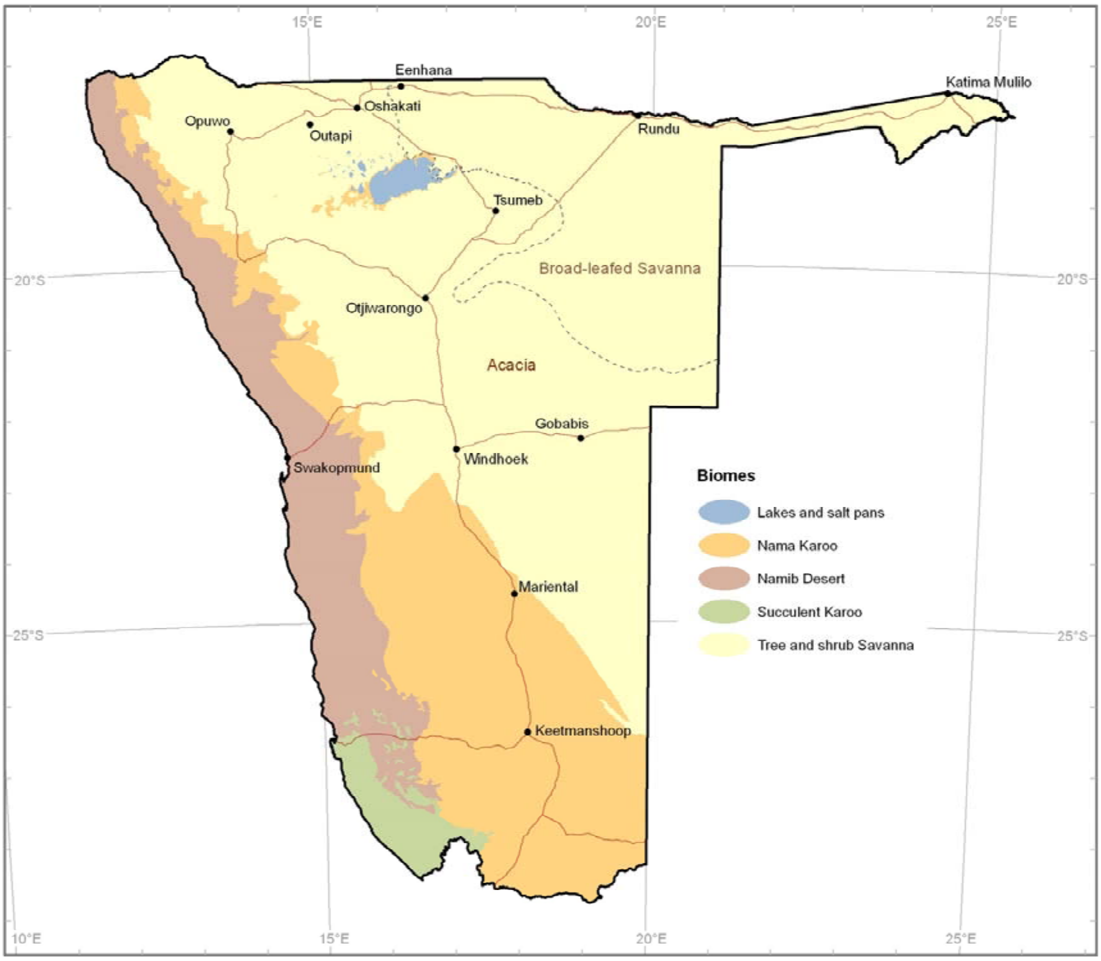


Figure 2.1. Main biomes of Namibia (from Mendelsohn *et al.* 2002)

2.2.1 Tree and shrub savanna

The Kalahari Basin extends over most of the north-eastern half of the country, where soils are dominated by deep sand. Tree and shrub savanna grows on most of this substrate, and this biome is further broken down into Broad-leafed and Acacia savannas. Broad-leafed savanna occurs in the far north-east, and trees characteristic of this biome form open woodland with varying bush and grass undergrowth. Several large river systems (Zambezi-Chobe-Linyanti, Kwando, Okavango) flow through the north-eastern part of Namibia, and this area is known for its wetlands with riverine forest, floodplains and river channels that support a great abundance and diversity of plants and animals not found elsewhere in the country. The broad-leafed savanna is characterised by average annual rainfall above 450 mm, and fires (started mostly by people) are a common, almost annual occurrence (Mendelsohn & el Obeid 2005).

Acacia savanna is characterised by open expanses of grasslands dotted with mostly thorny *Acacia* trees but also includes areas where mopane (*Colophospermum mopane*) and other trees such as *Commiphora* dominate. Landscapes are more hilly and rocky in the highland areas such as Khomas Hochland, Otavi Mountainland and north-western parts, where soils are thinner and plant growth diminishes and grows smaller. Namibia's central area has moderate to dense cover of shrubs and small trees and some parts of this area are severely encroached with invader bush.

2.2.2 Nama Karoo

This biome covers most of the south-eastern part of the country and extends in a thin band along the escarpment, making a transition zone between savanna to the east and desert to the west. There is a varied assemblage of plant communities including shrubby vegetation and grasslands in the Kunene hills and central western plains, dwarf shrub savanna in the south central areas, and grasslands in the south. These variations reflect the variety of geological substrates, soils and landforms, which in turn are responsible for the high level of endemism that is found in this zone. A high proportion of Namibia's plant, bird and reptile species occur only in this zone in the north-western part of the country.

2.2.3 Namib Desert

The coastal band of the country is characterised by extreme aridity. Rainfall is very low (< 100 mm) and highly variable but a more consistent source of water is fog, although delivered in much smaller amounts. The cooling effect of the Benguela current and the fog that regularly penetrates up to 50-100 km inland moderates the temperature extremes experienced in the Namib. Sand dunes dominate the substrate between Luderitz and Walvis Bay, forming the main Namib Sand Sea, and occur in smaller dune fields in the southern and northern Namib. Gravel and sandy plains dotted with inselbergs characterise the remainder. Vegetation cover is sparse and confined to small plants – grasses and shrubs – and ephemeral washes are able to support more of such plants as well as scattered trees. The desert is cut by a number of west-flowing rivers which rise in the highlands further inland and create linear oases through the arid surroundings. Each river has an alluvial aquifer that supports trees and undergrowth and occasional springs, all of which contribute to the role of the rivers as lifelines crossing the Namib (Jacobsen *et al.* 1995).

2.2.4 Succulent Karoo

The southern Namib is separated as a biome in its own right due to the more abundant and distinct succulent vegetation that occurs there, mainly dependent on winter rainfall. Plant endemism is extremely high in this zone. The vegetation structure is classified as dwarf shrubland, and shows such great variety on account of the varied landscapes and processes – inselbergs, gypsum and sand plains, dune fields, varying fog penetration and wind corridors. The inselbergs and mountains are particularly diverse, harbouring many species with extremely restricted ranges (Mannheimer 2008).

2.2.5 Biodiversity and endemism hotspots

The south-west African arid zone, because of its low productivity, is endowed with modest diversity of species compared to more mesic habitats. What is most distinctive about Namibian biodiversity is its high degree of endemism (Barnard 1998). Overall terrestrial diversity of plants and animals is highest in the north-eastern parts of Namibia (Figure 2.2), because of the higher rainfall and presence of wetlands and forest habitats that are not found elsewhere in the country. Many species in the north are also more tropical, with ranges that extend into neighbouring countries to the north and north-east. Species richness is highest in Namibia's mesic wetlands and woodlands in the vertebrate classes particularly (Barnard 1998). Other zones of notably high diversity are centred on the karstveld (Tsumeb-Otavi area), in central areas of high ground, and in scattered areas further west and in the south. Habitat diversity is an important determining factor: plant and animal species are relatively more numerous where there are a variety of habitats situated close together (such as mountains slopes with different aspect, rock types, slopes and relief).

In invertebrate groups, both species richness and endemism is high in arid areas (Barnard 1998). Animals such as scorpions and solifuges are well adapted to arid conditions and show great substrate specificity, so that arid and semi-arid areas with a variety of microhabitats support relatively high numbers and abundance of these species (E.Griffin 1998, Mendelsohn *et al.* 2002). The Namib is recognized as a hotspot of invertebrate diversity (Seely & Griffin 1986).

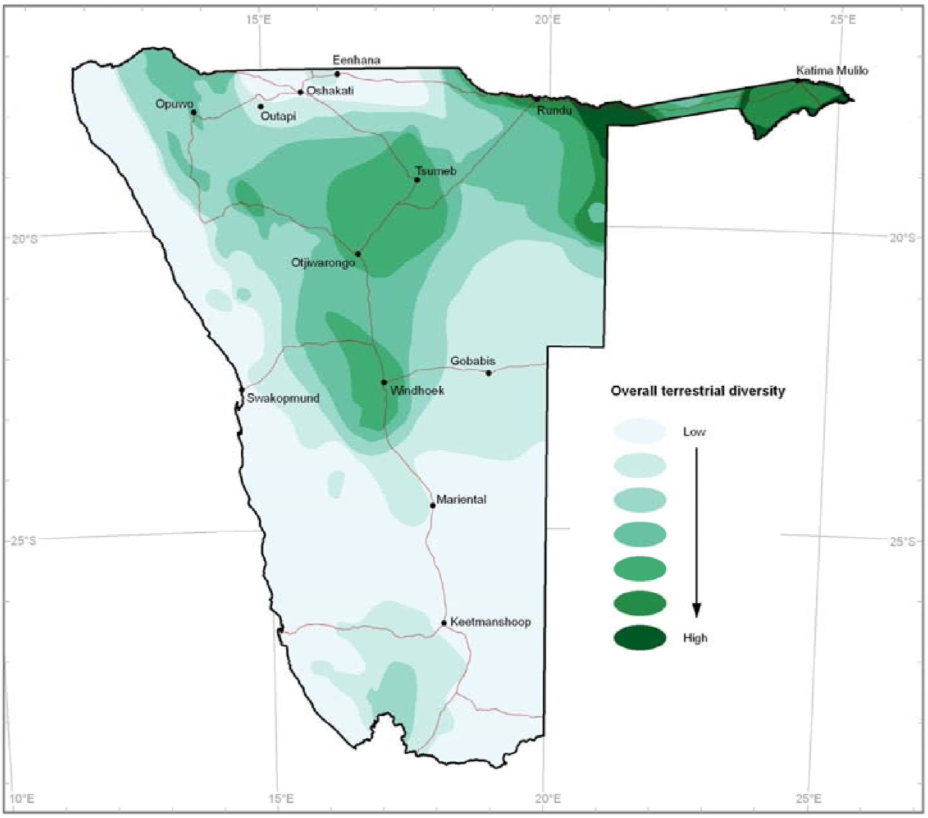


FIGURE 2.2. TOTAL BIOLOGICAL DIVERSITY IN NAMIBIA (FROM MENDELSOHN *ET AL.* 2002)

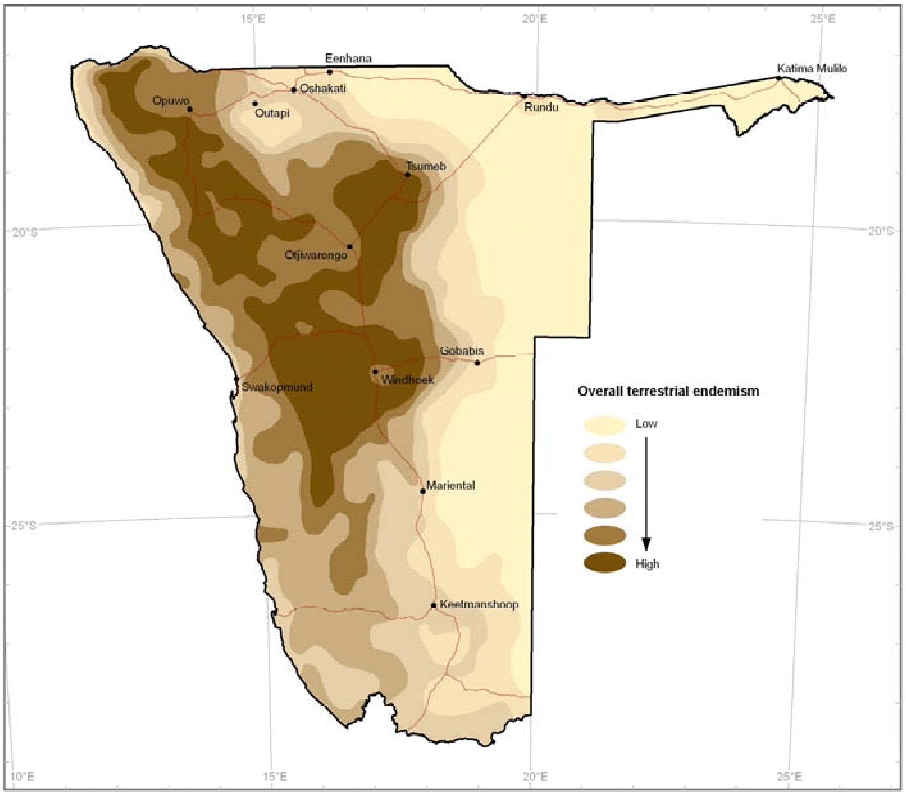


FIGURE 2.3 OVERALL DENSITY OF SPECIES ENDEMIC TO NAMIBIA (FROM MENDELSOHN *ET AL.* 2002)

Unlike the concentration of biodiversity in the north-east, the great majority of Namibia's endemic species are found in the dry western and north-western regions (Figure 2.3) (Barnard 1998, Mendelsohn *et al.* 2002). The patterns of endemism reflect the importance of arid habitats in supporting unique and specially adapted species.

Endemic species, particularly of birds, mammals and reptiles, are concentrated in the escarpment zone. In the Namib, endemics are associated with the dunes, rocky inselbergs and hills, and the sandy and gravel plains. For instance, approximately 60 reptile species (50% of all Namibian endemic reptiles) are endemic to, or found mainly in, Namibia's Namib Desert (M.Griffin 1998). In birds, the greatest diversity of southern African endemics is centred on the arid savanna and Karoo biomes and extends into the escarpment (Brown *et al.* 1998). Highland areas of the country, including Waterberg, Khomas Hochland, Karas Mountains, Brandberg, inselbergs in the Sperrgebiet and the karstveld are particularly important for many endemic plants (Mendelsohn *et al.* 2002). The Succulent Karoo biome is recognised as an important region of endemism (Barnard 1998).

Habitats of special ecological importance for both richness of species generally and of endemic species include (Barnard 1998):

- Inland wetlands (perennial and ephemeral);
- Mountains and inselbergs;
- The coastal zone;
- The Namib sand sea and adjacent gravel plains;
- The winter-rainfall desert zone; and
- Caves and sinkholes.

2.2.6 Distribution of terrestrial primary productivity

Following the overall rainfall pattern for the country, plant production shows a gradual increase from south-west to north-east (Figure 2.4).

The important features of the map are:

- Areas of highest plant production are in the broad-leafed woodlands of eastern Caprivi, western Kavango and eastern Ohangwena-Oshikoto Regions, and in the woodlands in the area of Tsumeb, Otavi and Grootfontein. Also noticeable on the map is the relatively high plant production from areas of mopane woodland around and north of Opuwo;
- Relatively high plant production centred around Otjiwarongo is due largely to bush encroachment; and
- A rapid decline from high to very low productivity across the western escarpment into the Namib proper in the northern half of the country.

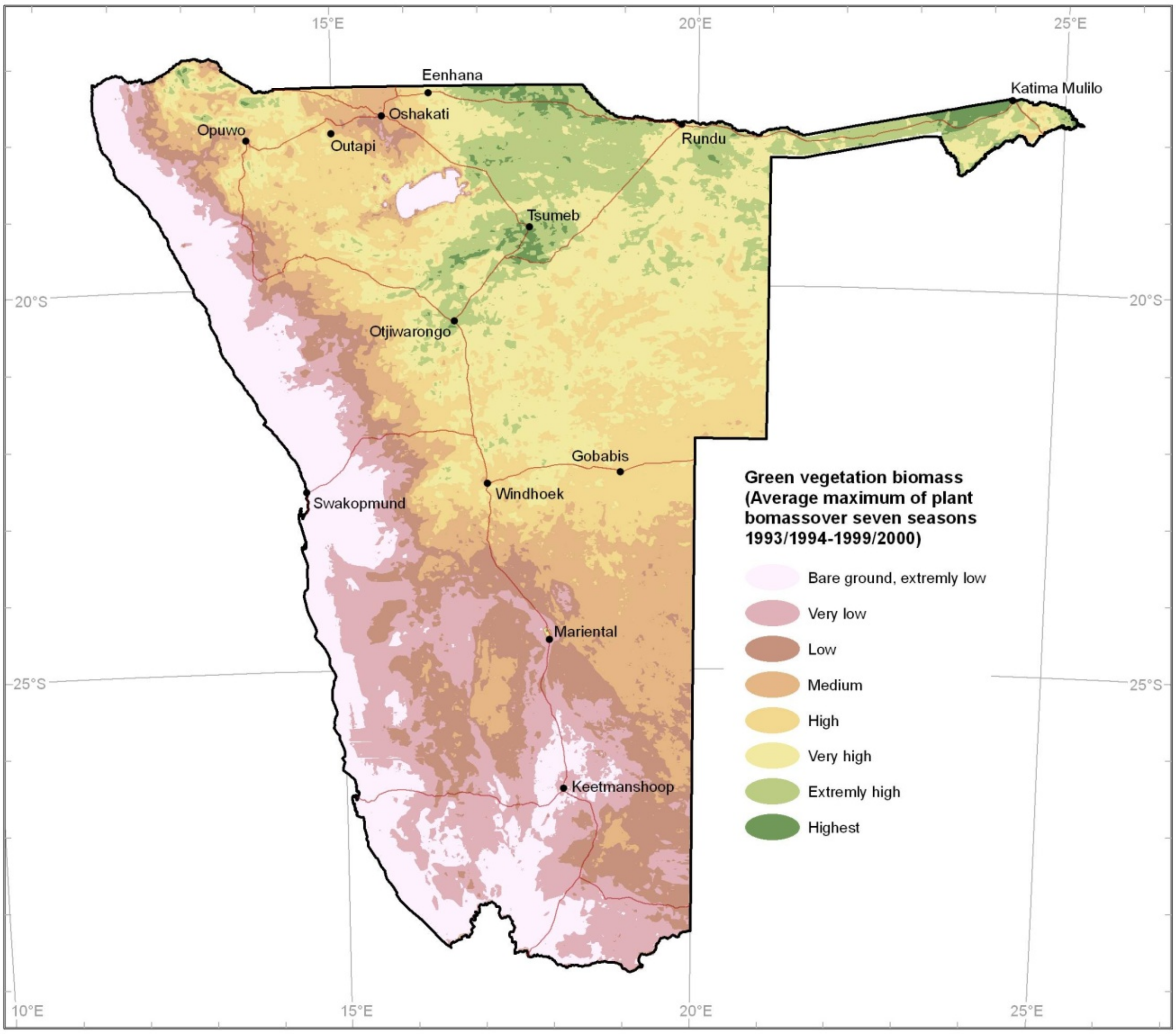


FIGURE 2.3. PLANT PRODUCTIVITY EXPRESSED AS GREEN VEGETATION BIOMASS IN NAMIBIA. (FROM MENDELSOHN ET AL. 2002)

2.3 INLAND AND COASTAL RIVERS AND WETLANDS

2.3.1 Inland rivers and wetlands

Perennial rivers occur only on the country's borders and are shared with neighbouring states. Periodically flooded areas fringing the rivers create wide floodplains with seasonally inundated vegetation, on the Kwando, Okavango and Zambezi Rivers which rise in wetter catchments in Angola and Zambia. The Kunene River in the north, and Orange River in the south, possess much smaller areas of seasonal flooding and comprise mostly a single channel with narrow flanking riparian woodland, passing through arid surroundings.

All remaining rivers within the country (with one or two small exceptions) are ephemeral, flowing only for a few days or weeks each year, and often not for several years in succession. Those flowing westwards across the Namib drain higher rainfall areas inland and create linear oases across the narrow desert strip. Sub-surface flow and water stored in alluvial sediments support trees and relatively dense vegetation in all the ephemeral rivers, and are therefore the focus of human settlements, livestock and wildlife. Some of these rivers do not reach the sea, but are blocked by dunes and terminate in pans such as Tsondab and Sossusvlei.

River channels in the north-central part of Namibia, flowing into the country from southern Angola, form the Cuvelai inland delta complex which terminates in Etosha Pan. These 'oshana' channels are fed by seasonal floodwaters and local rainfall, and are a key source of fish, nutrients and other wetland resources in Namibia's most densely inhabited rural regions. This large delta complex mostly covers communal land where small-scale crop and livestock agriculture takes place, and it terminates in the Etosha National Park.

Other ephemeral river courses in Namibia include those flowing south as part of the Orange River basin (including the Fish River and its many tributaries), and the east-flowing Nossob River and its tributaries which have not experienced proper flows since 1934 (Barnard 1998). All of these rivers are the focus of human settlements, providing year-round groundwater that supports riparian woodlands, people, their stock and wildlife.

Pans are important features over much of the country, with a concentration of large seasonally-filled pans found in eastern Otjozondjupa ('Bushmanland'). These are extremely important inland wetlands especially as breeding sites for many water birds. Many hundreds of small pans are scattered across the south-eastern part of the country, on Kalahari sands. They tend to hold water for very short periods only, up to a few weeks, and are fed entirely by local rainfall. Many salt pans close to the coast in the west are natural features but modern salt production has expanded them into commercial operations at Walvis Bay, Swakopmund and Cape Cross. Nevertheless, they are also critically important habitats for many coastal wetland birds.

Springs and seeps form small permanent or semi-permanent wetlands fed by groundwater. These often provide the only source of water to wildlife and people.

Namibia has a few natural lakes (such as the sinkhole Otjikoto and Guinas Lakes, and ephemeral Lake Oponono in the Cuvelai), and permanent bodies or water are mostly man-made. These include dams such as Hardap and von Bach, which have been built to secure water supply for settlements and farming. These dams provide relatively little value in terms of biodiversity or ecological value.

2.3.2 Coastal wetlands

Namibia's coastal wetlands comprise of extensive mud flats and shallow marine and estuarine habitats, and provide important feeding and breeding grounds to a large number of migratory birds, wading birds and seabirds (Maartens 2003).

The Walvis Bay Wetland supports more than 100 000 birds during summer and is recognised as the most important wetland in terms of bird diversity in southern Africa. The wetland at Sandwich Harbour supports up to 315 000 birds of 115 species in summer making it Southern Africa's single most important coastal wetland for migratory and resident birds. The Orange River Mouth is the sixth richest coastal wetland in southern Africa in terms of bird abundance and a total of 64 wetland species have been recorded here. Supporting at least 72 species of wetland birds, the Kunene River mouth is the second richest coastal wetland for birds in Namibia. In addition Nile Soft-Shelled Terrapins and Green Turtles have been found at the Kunene River mouth and Nile Crocodiles, Nile Monitors and five endemic fish species have been recorded in the estuary itself.

There are three Ramsar Wetlands of International importance along the coast of Namibia: the wetlands of Walvis Bay, Sandwich Harbour and the Orange River Mouth. Both Sandwich Harbour and the Orange River mouth are protected in Namibia within National Parks and the Walvis Bay wetland will be once the Swakopmund-Walvis Bay area is proclaimed as a National Park. In addition, the Kunene River Mouth, Cape Cross Lagoons and the Lüderitz Lagoon are all managed in accordance with the Ramsar Convention guidelines despite their lack of Ramsar status (Maartens 2003).

2.4 COASTAL HABITATS AND BIODIVERSITY

The 1570 km coast of Namibia extends between the Kunene River mouth in the north and the Orange River mouth in the south, and consists mainly of long stretches of sandy beaches interspersed with rocky shores and rocky outcrops (Currie *et al.* 2008). There are several islands situated off the southern half of Namibia's coast, perennial rivers on the northern and southern boundaries and 10 ephemeral rivers that occasionally reach the sea on the northern half of the coast (Morant 1999, Molloy 2003a). The coast is relatively straight with three important bays and inlets; these are Lüderitz Bay, Sandwich Harbour and Walvis Bay (Molloy 2003b).

The intertidal habitats stretching between the Orange River mouth and Lüderitz falls within the Namaqua zoogeographic province, and those north of Lüderitz to the Kunene River mouth fall within the Namib zoogeographic province. The Namaqua province (cool temperate southwest) is a continuation of the Namaqua province of South Africa, while the Namib province (warm-temperate northwest) extends into southern Angola.

2.4.1 Sandy shores

The baseline information for intertidal sandy fauna of northern Namibia consists of surveys conducted on three beaches during the 1980s (Maartens 2003). The surveys indicated that the diversity of macrofauna was generally low and mostly comprised terrestrial insect and arachnid species associated with washed up kelp wracks, while nematodes and platyhelminthes were the most abundant meiofauna (Tarr *et al.* 1985 cited by Maartens 2003). Records of several tropical intertidal species are thought to be indicative of a transition zone between tropical and temperate zoogeographic provinces on the northern Namibian coast (Tarr *et al.* 1985 cited by Sakko 1998).

The fauna on the sandy shores of central and southern Namibia is similar to that found on the west coast of South Africa (Maartens 2003). These shores support a low abundance, diversity and biomass of intertidal fauna, dominated by isopods and amphipods.

The central coast area of Namibia holds the highest densities of shore birds (up to 450 birds per km) in southern Africa. Declines in Damara Tern numbers have been reported and a 3-4 fold decline of all shore birds was reported at Elizabeth Bay between 1993 and 2002 (Maartens 2003). Green turtles have been reported on the beaches of the Skeleton Coast, but breeding has not been recorded there (Morant 1999).

2.4.2 Rocky Shores

Rocky shores provide a variety of niches which support a greater abundance of seaweeds and invertebrates than sandy shores. The Namibian rocky shores support the highest biomass of mussels per unit area in the southern African region (Currie *et al.* 2008); however the diversity of fauna is relatively low (Morant 1999).

Rocky shore faunal diversity is highest on the southern shores (total of 202 species belonging to 8 phyla) and the lowest on the northern shores (53 species belonging to seven phyla; Maartens 2003). Similarly the biodiversity of the flora decreases from south to north. This pattern is thought to be due to temperature patterns, the counter-current intrusion from the warm Angola current in the north, increased sand/silt inundation and a reduction in habitat availability and diversity (Maartens 2003).

The communities of flora on the southern shores were typical to that found off the west coast of South Africa and were classified as cool-temperate (Morant 1999), while the most dominant flora on the northern shores were tropical forms (Maartens 2003). Eighty percent of the seaweed species recorded in Namibia are temperate species that occur on the west coast of South Africa (Engeldow *et al.* 1992, cited by Morant 1999). None are endemic to Namibia (Maartens 2003).

The rocky shores extend as subtidal reefs supporting kelp bed communities which in turn provide food, shelter and protection to juvenile and vulnerable marine organisms (Currie *et al.* 2008). In addition the rocky shores provide important breeding areas for birds (Currie *et al.* 2008).

2.4.3 Islands

There are a number of small islands, islets and rocks off the southern half of Namibia's coast that are important breeding sites for seabirds and seals. These islands have played an important historical role as sites for guano and seal harvesting, and guano harvesting continues today to a limited extent (Molloy 2003b). The islands fall within the cool-temperate Namaqua province (Currie *et al.* 2008).

The most important coastal seabird breeding islands include Mercury Island, often supporting more than 15 000 birds; Ichaboe Island, regularly supporting over 50 000 seabirds of at least eight species; and Possession Island, supporting more than 20 000 seabirds (Maartens 2003). The islands are important for endangered species such as the Damara Tern (endemic to south-western Africa), White Pelican, Cape Gannet and Greater and Lesser Flamingos; the critically endangered African Penguin; and 90% of the world's endangered Bank Cormorants (Maartens 2003). There have been reports of serious declines in the seabird colonies on the Namibian coast, particularly Penguins, Bank Cormorants and Cape Gannets (Maartens 2003).

2.4.4 Subtidal benthic communities

Most of the shallow subtidal reefs are located along the southern section of Namibia between Chameis Bay and Mercury Island (Currie *et al.* 2008). They generally have a low diversity of species and a high abundance of individuals. The benthic communities are dominated by mussels, whelks, urchins, sea cucumbers, anemones and various algae including kelp (Sakko 1998). These subtidal reefs are critical habitats and recruitment grounds for the commercially-important rock lobster (*Jasus lalandii*) which occurs seasonally in high densities and is a dominant predator in benthic communities (Currie *et al.* 2008).

The substrate north of Spencer Bay consists mostly of mixed rock and sand with fewer rocky reefs than in the southern area (Currie *et al.* 2008).

2.4.5 Near-shore fish

There are some 91 species of bony fish and 30 species of cartilaginous fish living in depths of less than 30m off Namibia's coast (Sakko 1998). The majority of these are bottom dwellers that feed on seaweeds, benthic invertebrates and small fish, however there are some notable exceptions, such as the pilchard (*Sardinops ocellatus*) and anchovy (*Engraulis capensis*), which are pelagic filter feeders (Sakko 1998).

The principle nearshore species taken by recreational anglers are kob (*Argyrosomus inodorus*), blacktail (*Diplodus sargus*), galjoen (*Coracinus capansis*) and west coast steenbras (*Lithognathus aureti*) (Morant 1999, Hampton 2003). Warm water species such as garrick (*Lichia amia*), shad (*Pomatomus saltatrix*) and spotted grunter (*Pomadasys jubelini*) are found off Namibia's northern shores and especially around the Kunene River mouth (Sakko 1998).

The major small pelagic fisheries in Namibia are for pilchard, which spawn off Walvis Bay and the Skeleton coast; juvenile Cape horse mackerel (*Trachurus capensis*), which are believed to originate from spawning stock in northern Namibia; and anchovy, which spawn north of Walvis Bay (Hampton *et al.* 1999, Mendelsohn *et al.* 2002, Hampton 2003). All of these species generally occur in shallow water within 50 km of the coast. Snoek (*Thyrsites atun*), the most important inshore commercial linefish, is found from southern Angola to Cape Agulhas and it is believed that there are separate populations in Namibia and South Africa (Hampton *et al.* 1999).

2.4.6 Marine mammals and reptiles

The coastal waters of Namibia are breeding areas for several important marine mammals and a total of 25 cetacean species have been recorded, including southern right and humpback whales and the endemic Benguela (Heavisides) dolphin (Morant 1999). The Cape fur seal (*Arctocephalus pusilus*) is abundant in Namibian coastal waters and a total of 16 breeding colonies have been recorded (Morant 1999). A population of green turtles has been observed feeding on sea grasses and basking in the warmer waters of the Kunene River mouth and the leatherback turtle is thought to occur off the coast of Namibia (Morant 1999).

2.5 Shelf habitats and biodiversity

Namibia's continental shelf is generally narrow. It is widest at the Orange River mouth and Walvis Bay and narrowest at Lüderitz and southern Angola (Sakko 1998). The pelagic habitat over the continental shelf of Namibia is rich in nutrients and supports a substantial community of fish and other organisms, many of which are important commercial fishery resources (Sakko 1998).

2.5.1 Plankton

Phytoplankton are the primary producers in most marine ecosystems. The production of phytoplankton in the BCLME is dependent on the supply of nutrients by upwelling events and is therefore ultimately dependant on the occurrence of wind in the region (Sakko 1998).

The dominant phytoplankton in the BCLME belongs to the diatom group (at least 184 species recorded) which undergo rapid blooms after upwelling events (Sakko 1998). None are endemic to Namibia (Sakko 1998). Dinoflagellates are the phytoplankton most often associated with harmful algal blooms (HABs) in the Benguela (Maartens 2003). HABs develop when winds and currents move blooms inshore. HABs have occurred most frequently in the northern Benguela towards the end of the upwelling season, and in the southern Benguela during periods of light onshore winds and downwelling associated with *El Niño* events (Maartens 2003).

The zooplankton of the BCLME has a relatively low species diversity, high abundance and limited endemism (Maartens 2003). Copepods are the most abundant and diverse group (243 species) of zooplankton off Namibia (Sakko 1998). The eggs and larvae of invertebrates and pelagic and demersal fish contribute substantially to the zooplankton biomass in Namibian waters (Maartens 2003).

2.5.2 Fish

The most valuable commercial fish in Namibia are the shallow and deep water Cape hakes (*Merluccius capensis* and *M. Paradoxus*), which spawn off the central Namibian coast and are harvested along the entire length of the coast; adult Cape horse mackerel (*Trachurus capensis*), which are believed to spawn off the north coast of Namibia; and monkfish (*Lophius spp.*), which spawn off the Orange River mouth and Walvis Bay (Hampton *et al.* 1999, Mendelsohn *et al.* 2002, Hampton 2003). The valuable, long-lived, slow-growing orange roughy (*Hoplostethus atlanticus*) are targeted by a deep water trawl fishery on the outer Namibian shelf.

The most important large pelagic species are the albacore or longfin tuna (*Thunnus alalunga*), which are believed to be part of a single southern Atlantic stock; bigeye tuna (*T. obesus*); swordfish (*Xiphius gladius*); and large pelagic sharks (Hampton *et al.* 1999, Hampton 2003).

2.5.3 Pelagic seabirds

A large number of pelagic seabirds exploit the Benguela fish stocks. The majority them occur in the offshore waters of northern Namibia and it is suggested that this is due to the higher productivity and availability of pelagic prey north of the Lüderitz upwelling cell. None are endemic to Namibia.

3 LAND USE AND CONSERVATION

3.1 THE PROTECTED AREAS NETWORK

The national parks network (also called the protected areas network or PAN) covers some 16.6% of the terrestrial area of Namibia. However, the PAN is not the only form of conservation in Namibia. The state has created a policy and legislative framework for freehold farms, communal conservancies and community forests to acquire rights over wildlife, trees and non-timber products, and tourism. These rights confer both responsibilities and economic benefits to the legal custodians of these resources. This policy framework has led to ever-increasing areas of land being converted to indigenous biodiversity production systems, including wildlife, tourism and forestry, a significant increase in wildlife numbers and diversity across the country through effective local management and reintroduction initiatives, and dramatic growth in the contribution of these sectors to the national economy.

Communal conservancies now cover about 15.7% of the country and community forests about 0.5%. The amount and distribution of freehold land under exclusive wildlife management, under mixed farming systems of wildlife and domestic livestock, and under mainly livestock with low levels of wildlife management, are not presently recorded. However, the total area managed for wildlife either exclusively, or as part of mixed farming systems is significant, as over 80% of Namibia's wildlife (estimated at more than 2 million head) occurs on freehold land, almost 700 farms covering over 3.5 million ha are registered as trophy hunting farms and, in 2005, over 80% of accommodation facilities for tourists were on freehold land.

There has been a huge growth in the number of tourism establishments in Namibia over the past 10 years, with some 450 establishments by 2005 and over 1 000 by 2008, but the percentage on freehold land has probably not changed much. There has also been a movement towards the establishment of private protected areas with a focus on tourism, but as these are informal and are not recorded on a national inventory. They are estimated to cover at least 0.5 million ha. The state, through non-legislative means, promoted the concept of freehold conservancies, encouraging freehold farms to work together to manage their wildlife across larger landscapes in a collaborative manner. Freehold conservancies now cover about 6.1% of the country. The national parks network, communal and freehold conservancies and community forests are shown in Figure 3.1.

3.1.1 Biome and vegetation coverage

The proclamation of most protected areas in Namibia pre-dated the emergence of biodiversity conservation science. Parks were established in areas that were perceived to have little other value, such as deserts that were unsuitable for farming, as buffer zones between settler farmers and indigenous people, and for the protection of game animals. As a result, protected areas are not evenly distributed between the different landscapes, biomes and vegetation types in the country (Figure 3.2). The Namib Desert and Succulent Karoo biomes have 75% and 90% respectively of their areas protected in national parks while the Nama Karoo, Acacia Savanna and Broad-leafed Savanna biomes have just 5%, 4.5% and 7.9% respectively of their areas in national parks. The percentage of each biome under different forms of conservation management is shown in Table 3.1. It is clear that communal and freehold conservancies make a particularly important contribution to national conservation targets in the Nama Karoo (14.4%), the Acacia Savanna (25.5%) and the Broad-leafed Savanna (31%) biomes, where the national parks network is under-represented.

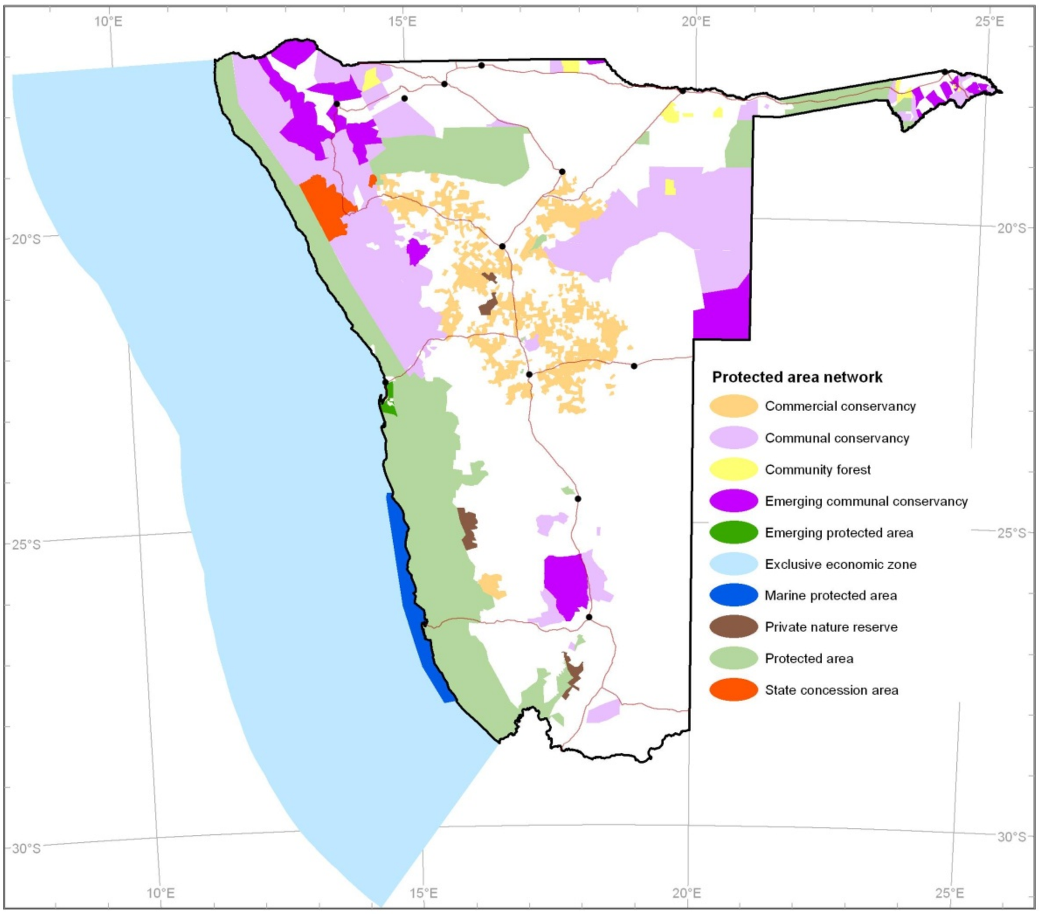


FIGURE 3.1. AREAS UNDER VARIOUS KINDS OF CONSERVATION MANAGEMENT IN NAMIBIA

Of Namibia's 29 vegetation types (Figure 3.3), 13 have less than 10% of their respective areas protected in national parks. Five have more than 10% of their areas covered by conservancies.

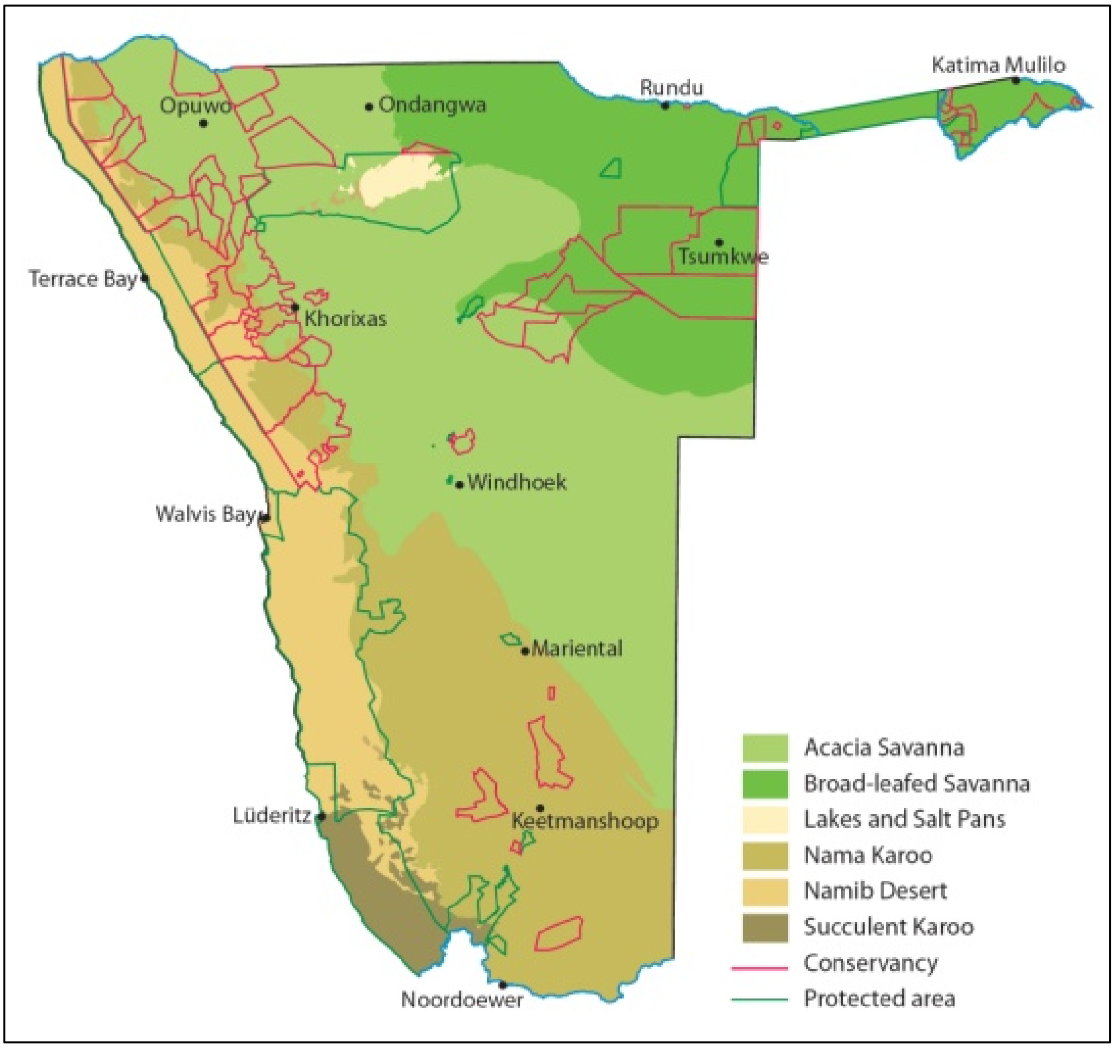


FIGURE 3.2. AREAS UNDER DIFFERENT FORMS OF CONSERVATION MANAGEMENT IN NAMIBIA, MAPPED AGAINST THE BIOMES IN THE COUNTRY

TABLE 3.1. PERCENTAGE OF EACH BIOME UNDER DIFFERENT FORMS OF CONSERVATION MANAGEMENT

Biome	Communal conservancy	Community Forest	Conservancy-Community Forest overlap	Overlap Tourism Concession	Freehold Conservancy	National Park	Total under conservation management
Total area of Namibia	15.7	0.5	0.2	0.8	6.1	16.6	39.4
Lakes and salt pans	0.7	0.0	0.0	0.0	0.0	96.8	97.5
Nama Karoo	13.8	0.0	0.0	1.4	0.6	5.0	20.8
Namib Desert	13.9	0.0	0.0	3.2	0.6	74.9	92.5
Succulent Karoo	0.0	0.0	0.0	0.0	0.0	90.5	90.5
Acacia Savanna	12.1	0.3	0.3	0.2	13.4	4.5	30.3
Broad-leafed Savanna	29.1	1.9	0.5	0.0	1.9	7.9	40.3

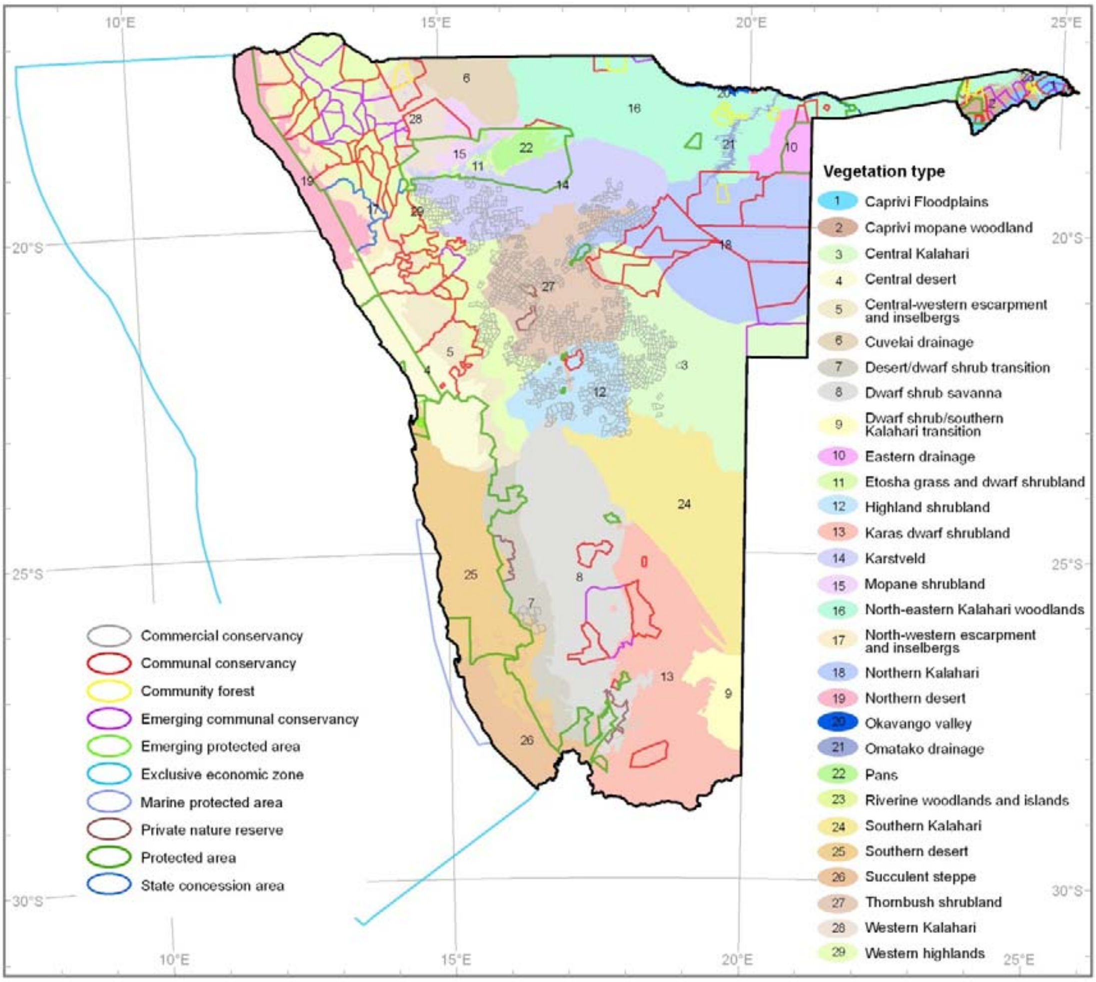


FIGURE 3.3. AREAS UNDER DIFFERENT FORMS OF CONSERVATION MANAGEMENT IN NAMIBIA MAPPED AGAINST THE VEGETATION UNITS IN THE COUNTRY

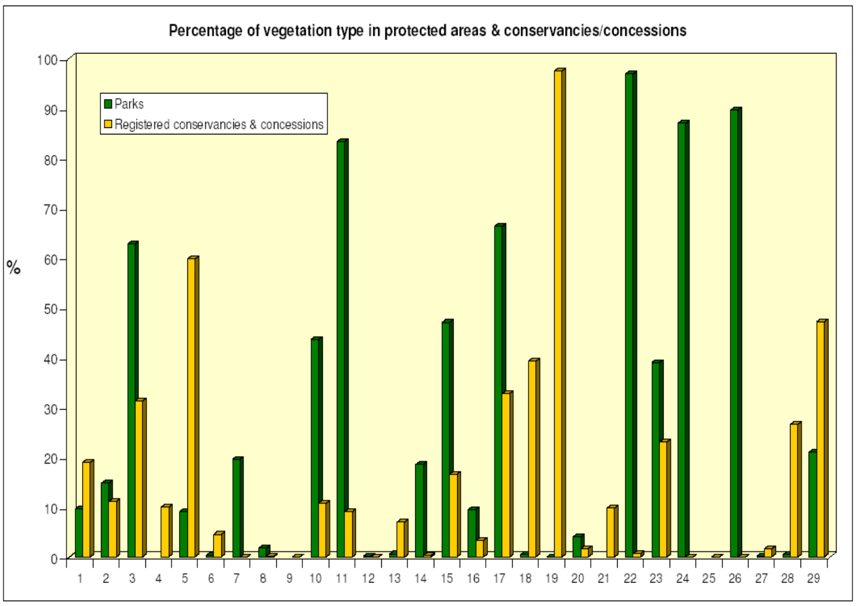


FIGURE 3.4. THE PERCENTAGE OF VEGETATION TYPES (1-29 FROM FIGURE 3.3) IN AREAS OF CONSERVATION MANAGEMENT IN NAMIBIA

3.2 Marine and Coastal Conservation

The Ministry of Fisheries and Marine Resources (MFMR) has recognised that the BCLME and the associated resources are essential for the socio-economic welfare of Namibia. Many important fish stocks had been severely depleted by 1990 through poor management and continue to be threatened by overfishing, while the ecosystems as a whole are threatened by nearshore and offshore mining activities, overfishing, oil spills and other vessel source pollution, and habitat loss. The MFMR acknowledges the importance of maintaining the health and integrity of Namibia's valuable marine ecosystems and has agreed to embrace an "Ecosystems Approach to Fisheries Management" (EAF). This intends to promote the responsible and sustainable use of its fish stocks and sustain the health of the northern Benguela ecosystem for current and future generations.

The declaration of a proportion of Namibia's marine areas as Marine Protected Areas (MPAs) is a strategy that forms part of the EAF approach (Currie *et al.* 2008). Areas to be considered as potential MPAs were identified and include the Orange River wetland; all the islands and marine areas immediately around the islands; the main African penguin, bank cormorant, and crowned cormorant feeding sites; lobster sanctuaries; whale calving sites; and air space within 1000 feet above all islands and main seal colonies (NACOMA 2009).

The first MPA, the Namibian Islands MPA was launched in July 2009 and proclaimed under section 51 of the Marine Resources Act (MRA) of 2001 (NACOMA 2009). The MPA stretches over 400 km from Chamais Bay to Meob Bay and 30 km offshore (Figure 3.5). Both lobster sanctuaries, 10 islands and 8 islets or rocks are incorporated within the MPA. The MPA provides protection to important nursery grounds for larval stages of pelagic fish, intertidal habitats, subtidal rocky reefs and kelp forests; and breeding areas for Heaviside's dolphin (Currie *et al.* 2008). There are also two lobster sanctuaries on Namibia's coast, at Ichaboe and Lüderitz (Currie *et al.* 2008).

The Namibian government has recently decided to expand its network of coastal National Parks so that the entire coastline of Namibia is incorporated within National Parks (Brown 2009a). The Sperrgebiet was proclaimed as a National Park on 1 December 2008. This southern section of Namibia's coast has suffered considerable damage due to diamond mining and the Namdeb Diamond Corporation is in the process of restoring affected areas to as near a natural state as possible. In addition Namibia's Cabinet has committed to take the following steps:

- Proclaim the Swakopmund-Walvis Bay area as a National Park
- Upgrade the status of the old National West Coast Tourist Recreation Area to a National Park (Brown 2009)

There has also been a proposal to join all of the coastal National Parks and the Namibian Island Marine Protected Area together to form one large National Park, known provisionally as the "Namib-Skeleton Coast National Park" (Brown 2009).

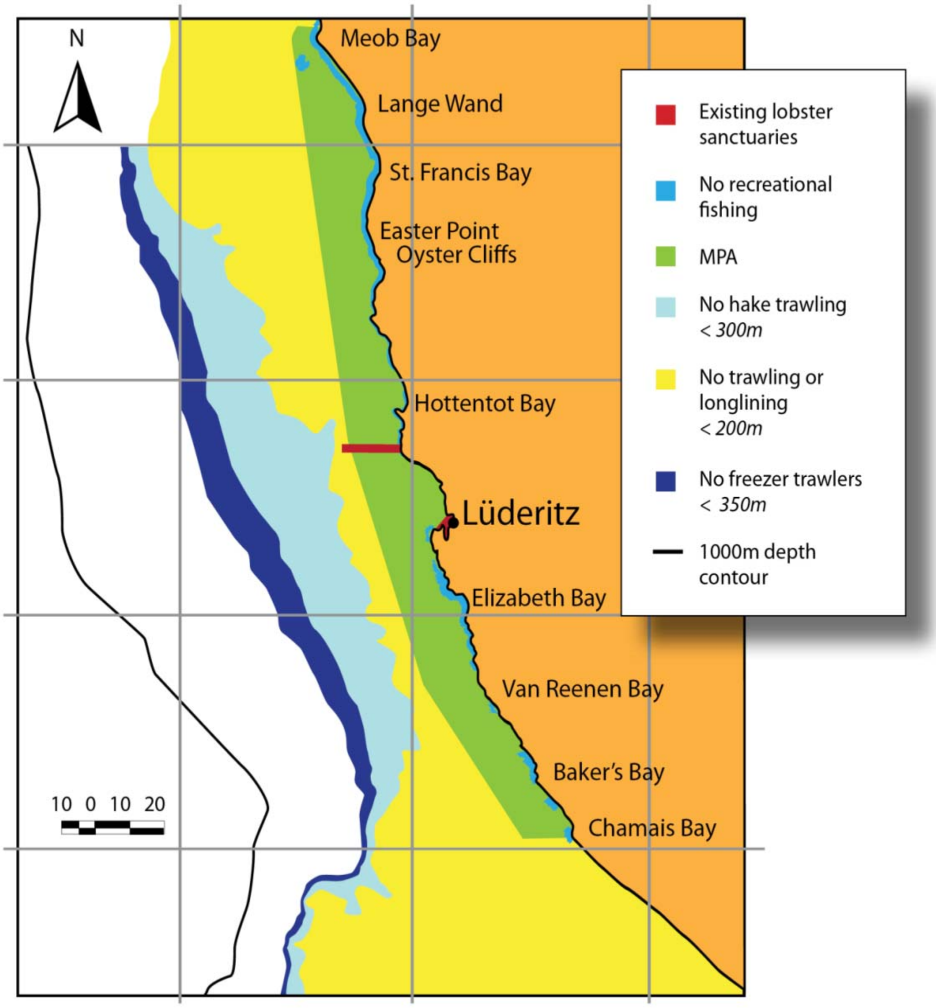


FIGURE 3.5. NAMIBIAN ISLAND MARINE PROTECTED AREA SOURCE: MFMR PAMPHLET 2009 (HTTP://WWW.NACOMA.ORG.NA/DOWNLOADING/MPA_PAMPHLET_WEB.PDF)

3.3 MAIN LAND USES OUTSIDE OF PROTECTED AREAS

Land uses outside of protected areas are still generally defined by broad farming practices (Figure 3.6). In the extreme north, where about 60% of Namibia's human population resides (and over 80% of the rural population), mixed subsistence small-scale cereal production and livestock husbandry are practiced on about 5.5 million ha (Mendelsohn 2006). This area supports about 600 000 head of cattle, 950 000 goats and 44 000 sheep - 25%, 40% and 2% respectively of the national herds. However, this only tells part of the story. Over 80% of households plant less than 4 ha per year, over 55% of farmers have no cattle and over 40% have no small stock (Mendelsohn 2006). Of the farmers with livestock, fewer than 20% have over 30 head of cattle and/or small stock. The average value of crops and livestock produced per year by a typical rural household is about N$6 000. This is only about 35% more than an annual pension. Far more of the household income is derived from non-farming activities, particularly wages, pensions and remittances sent by family members working elsewhere (Mendelsohn 2006). Also important are timber and non-timber forest products, fish, wildlife and tourism benefits. About 14% of this area is under conservancies and community forests. About 73% of total household income comes from non-farming activities in north-central Namibia, while in Kavango the figure is about 82%.

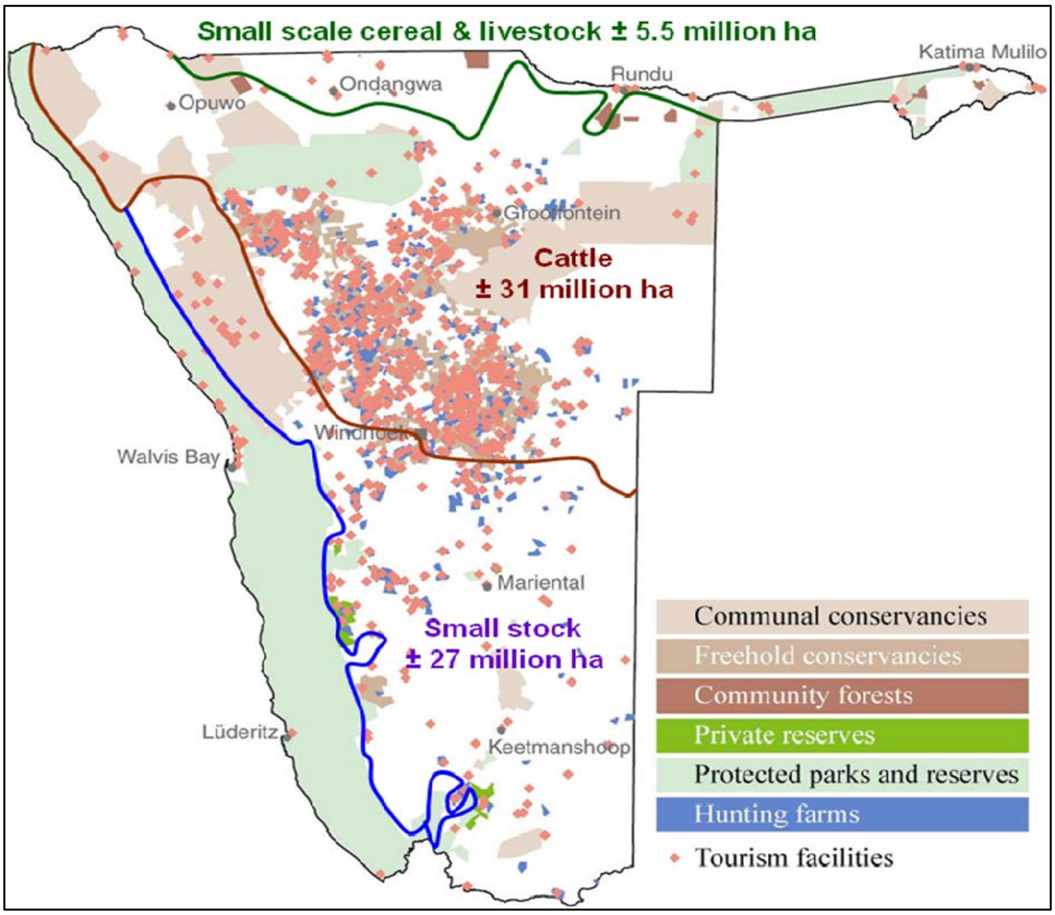


FIGURE 3.6. AREAS UNDER DIFFERENT FORMS OF CONSERVATION MANAGEMENT IN NAMIBIA, MAPPED AGAINST THE MAIN AGRICULTURAL PRACTICES

Cattle are farmed mainly in the central-northern areas, covering some 31 million ha that support about 1.4 million animals (64% of the national herd) and about 9% of the rural human population. Again, the land use situation is far more complex than this suggests. About 34% of the area falls within communal and freehold conservancies, and about 85% of registered hunting farms and more than 65% of Namibia's registered tourism establishments occur here.

Small stock is farmed mainly in the south and west of Namibia, covering about 27 million ha. The area supports about 2.1 million and 0.65 million head of sheep and goats respectively (86% and 27% respectively of the national herds) and less than 5% of the rural human population (Mendelsohn 2006). About 19% of the area comprises communal and freehold conservancies and private protected areas, mainly in the extreme west and south, along the Namib-Skeleton Coast and the Fish River Canyon Parks where the rainfall averages below 100mm and where conventional farming has proven not to be viable.

Only some 40 000 ha in Namibia are under intensive commercial cropping. These areas fall within the high rainfall cell in the Grootfontein-Tsumeb-Otavi triangle, irrigated farms along the banks of the northern rivers, irrigated lands adjacent to the Hardap and Naute dams, irrigated lands from artesian aquifers in the Stampriet area, and irrigation projects along the Orange River.

An important outcome of Namibia's policy and legislative framework to devolve rights over wildlife, tourism and forestry to local land owners and custodians is that land adjacent to protected areas is often more suited and more profitable under wildlife and tourism than under conventional farming. This in turn has led to a significant reduction in park-neighbour boundary conflicts as neighbours begin to practice compatible land uses. For example, of all national park boundaries falling in communal areas, over 70% now have conservancy and tourism concession areas as neighbours (Figures 3.1 and 3.7). This offers huge opportunities for future collaboration, to enhance both ecological and economic values, to improve management, particularly at a landscape level, and to mitigate the impacts of climate change.

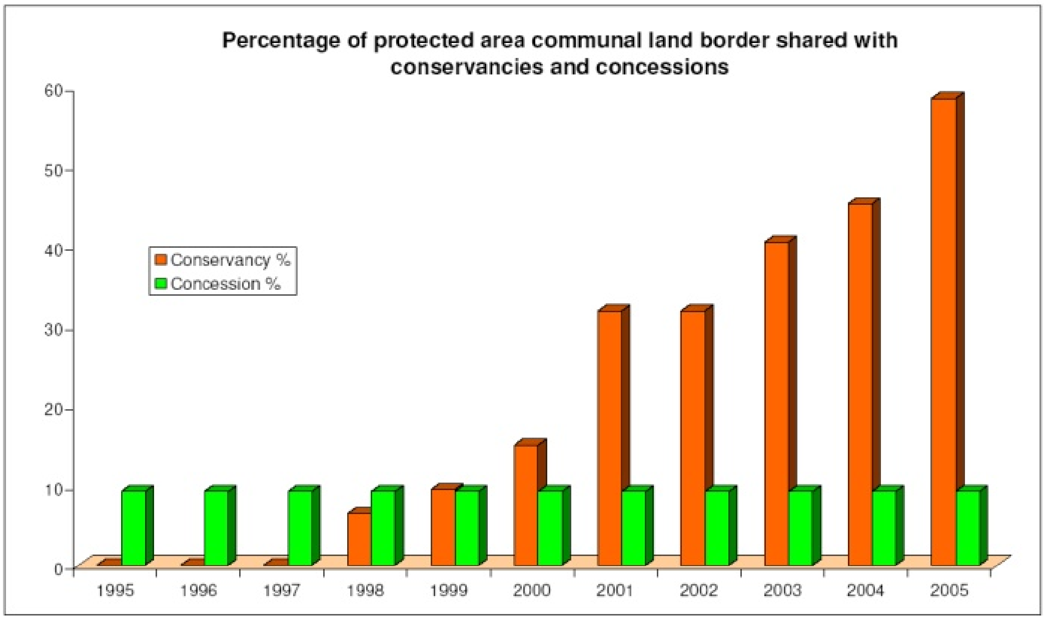


Figure 3.7. Percentage of protected area boundaries in communal areas that are shared with conservancy and tourism concession areas

The overall conservation landscape of Namibia, with its national parks, conservancies, community forests, private protected areas and other forms of freehold wildlife management, presents Namibia with unequivocal and unique conservation opportunities. The full extent of these opportunities has not yet been capitalised upon to any significant extent. The most important component to bear in mind is the economic driver behind this form of land use. Indigenous biodiversity production systems generally:

a) are more profitable than farming with a significantly higher return per hectare;
b) create more and better paid jobs than commercial agriculture;
c) are feasible and indeed may be highly profitable in desert areas where farming is not viable;
d) are less directly linked to primary production and thus less prone to the impacts of drought;
e) allow for diversification of livelihoods;
f) are not urban based and thus bring wealth, jobs and development into remote rural areas; and
g) lend themselves to co-management approaches that focus resources, capacity, marketing and collaborative involvement around defined areas, thereby promoting a landscape approach to land and natural resources management, creating networks and linkages between land under different ownership and management. This is a critical element to mitigate climate change impacts, and is particularly significant in arid and semi-arid zones where one of the most important adaptations to patchy and unpredictable water and food resources is animal mobility.

3.4 Vision for the development of Namibia's Protected Area system

3.4.1 The Parks Vision

In 2005 a "Conservation Needs Assessment" was undertaken as one component of the preparatory phase of the SPAN Project by Brown *et al.* (2005). This project identified priority threats and problems and ways to realign Namibia's protected area network for optimal conservation success, and undertook a needs assessment to identify optimal habitat protection to ensure protection of land and species not represented in protected areas. It also assessed data management requirements; evaluated the potential to proclaim World Heritage Sites, and reviewed control procedures concerning prospecting and mining in PAs. The recommendations of the conservation needs assessment are referred to in this report as the "Parks Vision", which formed the core principles of the SPAN Project design. In addition, an institutional capacity study (Booth *et al.* 2005) was undertaken that made recommendations for institutional realignment to give effect to the Parks Vision.

The overall vision is to effectively expand, manage and develop the park network of Namibia in order to adequately protect the biodiversity and landscapes of the country. The main objective is to devise a system of integrating land and natural resource management that transforms the current protected areas patchwork into a protected areas network, through creating incentives for all Namibians (MET, conservancies, private landowners and tourism operators) to work together toward a common goal. Key tasks for achieving the vision are described below.

It was proposed that protected areas are grouped into three regions that are consistent with respect to habitats, ecological processes, wildlife movements and future compatible land uses – the north-west, north-east and central-south regions (Figure 3.8).

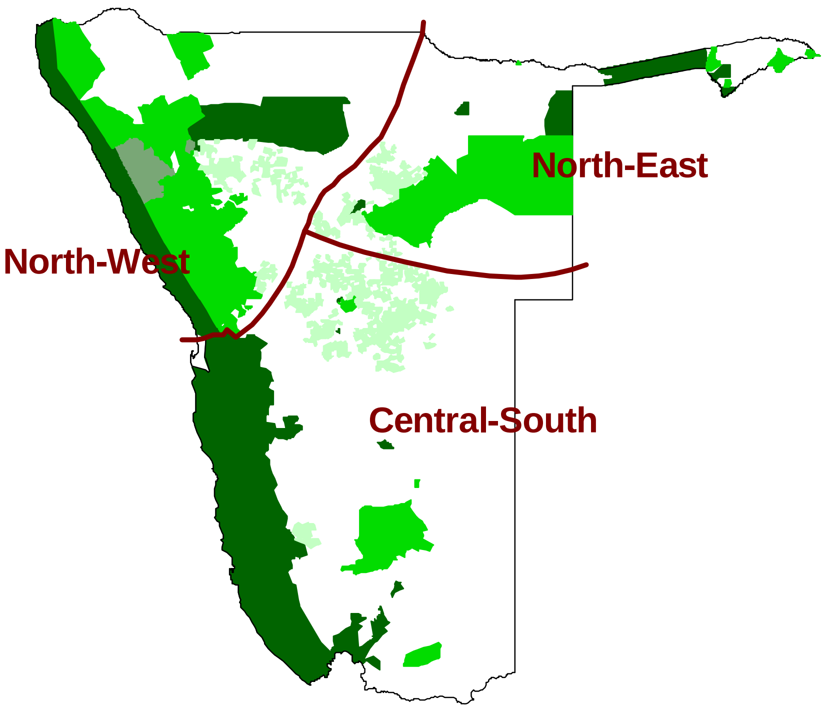


FIGURE 3.8. BREAKDOWN OF PROTECTED AREAS INTO THREE INTEGRATED REGIONS IN NAMIBIA (SOURCE: BROWN *ET AL.* 2005)

The key focus in the north-west region is on formalizing the linkages between Etosha and the Skeleton Coast Park via the Kunene conservancies, by expanding conservation areas and removing fences to provide ‘safe corridors’ to facilitate repopulation of former home ranges and reintroduction of certain species. In the north-east region, which includes Bwabwata National Park; Mamili, Mudumu and Mahango National Parks, Khaudum Game Park, the Mangetti Game Camp and Waterberg Plateau Park, the key focus is for establishing new conservancies to provide protection for the eastern floodplains in Caprivi, as well as improving ecological linkages within the transfrontier conservation area. In the central-south region, which includes the Namib-Naukluft Park

(5.07 million ha) and new Sperrgebiet Park, as well as the Huns Mountains/Ai-Ais/Fish River Canyon Park complex, Daan Viljoen Game Park, the Naute Dam, Hardap, Von Bach and Gross-Barmen Resorts, and Walvis Bay Nature Reserve, priorities are the revision and implementation of management plans for the protected areas and development of park infrastructure and operational capacity, including the enforcement of regulations on grazing of livestock, agriculture, resource harvesting, and tourist access. Linkages between conservation areas such as the Ais-Ais/ Huns Mountains and Fish River Canyon with the Sperrgebiet are required through forming partnerships to ensure appropriate land use compatible with the parks. A key focus will be monitoring of mining activity and enforcement of rehabilitation and controls on off-road driving.

The Parks Vision envisages partnerships with communities on communal land adjacent to parks, private landowners, tourism operators, NGOs, academic institutions, private interested individuals, and donor agencies with a joint focus on adopting pro-conservation land uses. Such partnerships could be forged through the formation of multi-stakeholder committees to direct natural resource management, tourism management and infrastructure development and maintenance. This approach supports Vision 2030 through promoting the participation of local communities and ensuring that tangible benefits accrue from the protected areas system through tourism and other activities.

Improved information research and data management was seen as integral to the parks vision. Key recommendations in this regard included the revitalisation of output oriented ecological research including the Etosha Ecological Institute, undertaking a 'data management needs assessment' process and designing a data management system and ensuring technical capacity and appropriate software and hardware (Brown *et al.* 2005). Closer linkage between tourism and wildlife management sectors are also called for to minimize the negative impact of tourism on the environment and to maximize the visitor experience and economic benefits of tourism.

It is important to note that the Parks Vision did not take the potential impacts of climate change into account.

3.4.2 MET's current mandate

The management of Namibia's protected areas falls within the responsibility of the Ministry of Environment and Tourism. The mandate of this ministry is derived from the Constitution of the Republic of Namibia and specifically Article 95, which requires the State to ensure "the maintenance of ecosystems, essential ecological processes and biological diversity and the utilization of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future".

Based on this broad mandate, MET's vision is "to be a role model in the conservation and sustainable use of biological diversity, promotion of natural resource-based livelihoods, environmental management and tourism development through innovation and partnerships in order to contribute to rural development and economic growth."

MET's mission statement, inspired by its vision, is "to promote biodiversity conservation in the Namibian environment through sustainable utilization of natural resources and tourism development for the maximum social and economic benefit of its citizens. As the custodian of our natural environment, the Ministry of Environment and Tourism will lead the sustainable development process towards the achievement of the goals of Vision 2030."

MET's Strategic Plan 2007/08 – 2010/11 contains nine strategic themes that provide "direction for future initiatives and define the organisation's priority areas". Themes pertinent to this study are as follows:

Theme 2: Manage protected areas, habitats and species.
"The MET will manage and develop protected areas, critical habitats and important plant and animal species in order to preserve biological diversity and ecosystems for use by present and future generations of Namibians and to generate global benefits. A devolved approach to the management of Parks will be followed with a focus on generating economic benefits."

Theme 3: Develop and support tourism.
"The MET will support the development of a robust tourism sector that includes private sector and community partners, and where appropriate, manage the tourism and natural resources assets under its control so that collectively this will increase the sector's contribution to GDP through poverty reduction and increased income distribution especially in rural areas."

Theme 4: Develop and support CBNRM
"The MET will continue to use CBNRM as an economic development and empowerment tool for rural communities through the consolidation and expansion of the conservancy program and its support mechanisms."

Theme 5: Support rural development (especially around parks)
"Namibia's protected areas provide an opportunity to stimulate local-level economic development. By actively engaging with neighbours and allowing the parks to become 'economic engines', MET has the opportunity to unlock the human and natural capital in these depressed rural areas. This will assist in poverty alleviation whilst simultaneously enhancing biodiversity conservation on a larger scale. This strategic theme is cross-cutting and involves CBNRM, protected area management and tourism development.

4 THE VALUE OF LAND AND NATURAL RESOURCES

4.1 Introduction

While the focus of this study is on biodiversity protection and the protected area system, in order to understand the potential implications of climate change and adaptation measures it is necessary to have a broad understanding of activities and values both within and outside of the protected area system. Thus this section attempts to summaries the activities and values of land under state protection and other types of tenure in different parts of Namibia.

Values of land and natural resources include those generated by 'direct uses' such agricultural production, natural resource harvesting and tourism, 'indirect uses', being the services provided by ecosystem functions that contribute to economic output, and 'non-use values', being the welfare value associated with people's appreciation of the existence of biodiversity, for example.

In this section, the direct use values of protected areas and surrounding land uses are described in terms of their contribution to the national income. This is the base line for measuring the likely economic impacts of climate change. The study focused on the land use activities. Only their direct impacts on the national economy were measured and no account was taken of backward and forward linkages associated with these land and natural resource uses. Thus value added through enterprises, supplying inputs to the land and resource use activities, or value added as a result of product processing such as meat processing, are excluded. The values are given in value added to the gross national product (GNP). Gross Domestic products for national income accounts data were used

Indirect use values and non-use values have not been well studied in Namibia, and brief descriptions, and where possible, estimates of these values are provided below.

4.2 Direct use values

4.2.1 Livestock production

Livestock are the mainstay of agricultural production and land use in Namibia. The broad-leafed savanna and acacia savanna biomes, found in the North East, and much of the North West broad integrated regions (Figure 3.8), are essentially dominated by cattle with lesser amounts of small stock. The Karoo biome found in most of the South Central broad integrated region is dominated by small stock (sheep and goat) production.

All livestock production is based on extensive systems, breeding and rearing or rearing of stock, based on the productivity of natural rangeland. Cattle are kept on commercial land on medium scale fenced farms averaging some 15 000 hectares each to produce beef. They are kept on communal land mostly in unfenced common property systems at small-scale around villages to produce meat milk, transport and as a store of wealth. They are also kept at medium scale cattle posts away from villages for the production of beef and as a store of wealth. Some commercial production in fenced land is taking place in communal land mainly to produce beef and as a store of wealth. Fenced commercial farms in the arid south are used to produce mutton sheep and karakul pelts with small amounts of wool and goats are kept for meat production. On communal land in the south, small scale production of sheep and goats, also for mutton, pelts and goat meat take place of common property or partly fenced properties. Relatively unimportant livestock systems include intensive dairy, pig, and ostrich production on commercial land.

Livestock stocking rates on rangeland are maintained by commercial farmers at around the most biologically productive carrying capacities (between 10 and 15 hectares per large stock equivalent unit in the north and north east, and between 15 and 25 hectares per large stock equivalent unit in the south and extreme west). In communal common property systems, due to open access, the stocking rates are closer to the biological limits, the ecological carrying capacity (between five and seven hectares per large stock equivalent unit in the north and north east, and between seven and 12 hectares per large stock equivalent unit in the south and extreme west). Herd and flock productivities (calving/lambing rates, mortality rates and animal growth rates) tend to reflect the stocking rates, highest in commercial land and lowest in the communal open access systems. Cattle post systems tend be between the two in terms of stocking rates and productivity.

4.2.2 Crop production

Both dryland (rainfed) and irrigated crop production is practiced in Namibia. Dryland crops are grown in association with small scale livestock production within agro-pastoral systems in the north and north east. Here low-input, small scale production of millet, maize, and sorghum, sometimes with associated field beans are grown Yields are low and, on average in one of three years, crops fail. Households producing crops tend to produce less than half of their annual subsistence needs, relying on cash purchases of to fill the gap. Medium to large scale dryland crop production takes place on commercial land, mostly in the North East integrated region, where maize is the primary crop.

Irrigated crop production takes place on commercial land in the south along the Orange and Fish rivers, and in communal land in the north east along the Okavango river and to a lesser extent in the north west, associated with the Kunene river in the Cuvelai. A variety of crops are produced including a mix of food crops and higher value cash crops. In the south table grape production is very significant. In addition, numerous other crops including maize and fodder crops are grown. In the north and east in mostly state run schemes the emphasis has been of food crops but increasing amounts of higher value crops are being introduced. The Green Scheme, described in Appendix 1 is an ambitious state-driven initiative aimed at significantly boosting irrigated crop production in the country. A notable feature of irrigated agriculture is that schemes in the south tend to be financially and economically viable while those in the north tend to have poor or non-existent financial economic viability. This is largely due to the location, remote from markets for inputs and products of the northern schemes (Barnes *et al.* 2009b).

The estimated direct economic contributions in terms of value added to the national income by agricultural land use and natural resources uses in Namibia are documented in Table 4.1 and Table 4.2 below. The basis for the agricultural values is the national accounts GDP by activity data, presented by IPPR (2009), which cover the period between 1990 and 2005, divided into commercial and communal agriculture. With the use of ratios from Sherbourne (2009) and Mendelsohn *et al.* (2006), the data were disaggregated into those attributable to commercial land livestock, communal land livestock, commercial land crop production, and communal land crop production. The commercial land livestock value was further disaggregated in to cattle and small stock. These values were projected to 2009 using the averages of real annual growth rates recorded between 1995 and 2005, and then inflated as appropriate to reflect 2009 prices. The annual growth rate applied for the commercial sector was 3.4% and that for communal sector was 2.1%.

TABLE 4.1. ESTIMATED DIRECT GROSS DOMESTIC PRODUCT CONTRIBUTED BY AGRICULTURAL PRODUCTION IN 2009 (N$ MILLION)

Region	North West	Central South	North East	Total
Livestock				
State protected areas	-	-	-	-
Communal land	364	26	130	521
Commercial land	786	590	590	1 965
Total	**1 151**	**616**	**720**	**2 486**
Crops				
State protected areas	-	-	-	-
Communal land	190	6	120	317
Commercial land	9	345	78	431
Total	**199**	**351**	**198**	**748**
Total agriculture				
State protected areas	-	-	-	-
Communal land	555	32	251	837
Commercial land	795	935	667	2 397
Total agriculture	**1 349**	**967**	**918**	**3 234**

TABLE 4.2. ESTIMATED DIRECT GROSS NATIONAL PRODUCT (GNP) CONTRIBUTED PER KM^2 BY AGRICULTURAL PRODUCTION IN 2009 (N$)

Direct GNP (N$ per km^2, 2009)				
Region	**North West**	**Central South**	**North East**	**Total**
Livestock				
State protected areas	-	-	-	-
Communal land	22.17	1.58	75.21	15.04
Commercial land	31.70	83.20	166.40	55.47
Total	**23.83**	**22.10**	**114.93**	**30.17**
Crops				
State protected areas	-	-	-	-
Communal land	11.57	0.39	69.59	9.16
Commercial land	0.35	48.70	21.92	12.18
Total	**4.12**	**12.62**	**31.63**	**9.08**
Total agriculture				
State protected areas	-	-	-	-
Communal land	33.73	1.97	144.80	24.20
Commercial land	32.04	131.90	188.32	67.64
Total agriculture	**27.94**	**34.72**	**146.56**	**39.25**

Agricultural production land uses generated some N$3.23 billion in terms of gross national product value added to national income. Some 77% of this is attributable to livestock. Commercial land contributes some 74% to total agricultural land use production value, and 79% of livestock production value.

4.2.3 Wildlife tourism

Tourism is a rapidly growing sector in Namibia and the leisure tourism component of this, which makes up some 40%, is dominated by nature-based pursuits. The nature-based component is attributable to a range of natural assets, including scenery and wildlife, are the most important. Barnes *et al.* (2009a) used data from the tourism survey of SIAPAC (2007), to estimate that wildlife contributed some 50% of the value of nature-based tourism. Most approximately 80% of the nature based tourism is non-consumptive, based in lodge or camp accommodation in the commercial land, state land (parks) and communal land. The other 20% consists of consumptive tourism, dominated by trophy hunting, which takes place mostly on commercial land but also on communal land and state land. Another, lesser, consumptive tourism component consists of marine shore angling. Tourism on commercial land takes the form of landholder enterprises, while that on state and communal takes the form of leasehold enterprises in joint venture partnerships with land holders - either government or local communities. Tourism as described above holds significant comparative advantages for Namibia, as it is not dependent entirely on scarce and erratic rainfall, and it can make use of the natural beauty inherent in the landscapes. Tourism potential tends to be localized around areas of high scenic value, and high wildlife concentrations.

A significant proportion of Namibia's wildlife tourism value is associated with the state protected area system. Based on average trip lengths, the total number of visitors to Namibian parks was estimated to be in the order of 180 000 in 2008, of whom 22% were regional and 47% were overseas visitors (Turpie *et al.* 2010). Based on recent estimates of average trip expenditure in Namibia by domestic, regional and overseas visitors to state protected areas, overall expenditure by wildlife-viewing protected area tourists was estimated to be in the order of N$2.35 billion. An additional N$96 million is estimated to be spent by tourists attracted by hunting concessions in protected areas, bringing the total to N$2.45 billion (Turpie *et al.* 2010). This resulted in an estimated direct contribution to GNP by state protected area tourists of N$1113 million, roughly 2.1% of GNP in 2008[1]. Of this, some N$433 is spent in state protected areas.

With the inclusion of expenditure by wildlife tourists that do not visit protected areas, the total direct contribution of wildlife tourism was estimated to be N$1800 million. The spatial distribution of this value is estimated in Table 4.3.

TABLE 4.3. ESTIMATED DIRECT GROSS DOMESTIC PRODUCT CONTRIBUTED BY WILDLIFE TOURISM IN 2009

Region	North West	Central South	North East	Total
Value N$ millions				
State protected areas	303	108	22	433
Communal land	66	30	5	101
Commercial land	380	380	506	1 266
Total	**749**	**518**	**533**	**1 800**
Value N$ per km^2				
State protected areas	43.06	25.04	21.91	35.06
Communal land	3.99	1.84	2.92	2.92
Commercial land	15.31	53.59	142.90	35.72
Overall	**15.51**	**18.61**	**85.12**	**21.85**

4.2.4 Harvesting of wildlife and plant resources

The use of wildlife other than through tourism takes place on commercial land through harvesting of game for own use, shoot and sell, live game capture and sale, and commercial culling. Most of this use takes place as supplementary enterprises alongside livestock production or tourism enterprises. Wildlife numbers have been increasing relative to livestock numbers which have been declining on commercial land.

[1] The total contribution to GNP, which includes multiplier effects or indirect contribution, was estimated to be N$2048 million, or 3.8% of GDP. However, in this study we are only considering direct contribution.

This is a function of higher perceived potential returns which have induced investments in wildlife within an improved property rights setting (Barnes & Jones 2009).

The use of plant resources takes place mostly on communal land and to a lesser extent on commercial land. Nearly all rural households harvest wood for fuel, poles for building, and non-timber wild plant products for food medicines and as raw materials for crafts. A significant charcoal industry is developing on commercial land where bush encroachment has been a problem. Inland fisheries are practiced in the wetlands of the north east and north. Here, households operate small scale to harvest fish from rivers and floodplains. The use of natural resources on communal land takes place generally by individual households in an open access setting. In a small number of areas common property management is being applied through community-based organisations such as conservancies and community forests.

Natural resources values were derived from various sources. Values for nature- based tourism, including trophy hunting tourism were derived from the wildlife accounts (Barnes *et al.* 2009a), and verified through comparison with the studies by Turpie *et al.* (2010) in the value of parks, and the tourism satellite accounts WTTC (2006) and NTB (2008). These values were subjected to real growth of 5.5% per annum to 2009, reflecting growth rates recorded and predicted by WTTC (2006) and adjusted to take account of the 2008 economic downturn. They were then also inflated to reflect 2009 prices. Values for wildlife use other than tourism were derived from the wildlife accounts (Barnes *et al.* 2009a). They were adjusted to 2009 values, through real growth at 7.2% per annum, based on average growth between 2004 and 2007, recorded by (T. Uahengo pers. comm., 2008), adjusted to take account of the 2008 economic downturn, and thereafter inflated accordingly.

Aggregate values were thus described according to the three integrated regions subdivided between state land, communal land and commercial land (Table 4.4). Values were then expressed per hectare within each land tenure category, again divided between the three integrated regions (Table 4.5).

Values for the use of wild plants were derived from the forest accounts which include the use of non-timber wild plant products (Barnes *et al.* 2005). They were adjusted to 2009 figures using the expected real annual growth rate of 4.2% predicted in the accounts, adjusted to take into account the 2008 economic downturn, and inflated accordingly. Values for inland fish use were derived from the 2008 values estimated by Barnes *et al.* (2009b), extrapolated to all regions with inland fisheries, and inflated accordingly. These values then disaggregated according to those attributable to state land (protected areas), communal land, and commercial land, and then disaggregated further in to the three broad integrated regions described in Figure 3.8. This was done using areas estimated using a dot-counting technique, and modified subjectively according the knowledge regarding the distribution of resources and land uses.

4.2.5 Summary

In terms of tourism, wildlife, and natural resource uses, some N$3.8 billion was generated in 2009. This is dominated by two main components, tourism (47%) and natural plant use (44%). Currently 70% of tourism value is generated in the commercial land, where property rights have allowed a rapid expansion of nature- and wildlife-based land uses. There remains significant potential for tourism development within parks and communal areas. Some 79% of natural plant use takes place in the communal areas, mostly in the north central part of the country (North West broad integrated region) where almost all rural households make use of wood and other natural products of plant origin. There is only localized overuse of these resources and overall they are relatively abundant making for high value added and rent generation, despite the fact use of the resources is effectively open access in nature.

TABLE 4.4. ESTIMATED DIRECT GROSS DOMESTIC PRODUCT CONTRIBUTED BY NON-TOURISM USE OF NATURAL RESOURCE IN 2009 (N$ MILLION)

Direct GNP (N$ millions 2009 Region	North West	Central South	North East	Total
Wildlife				
State protected areas	50	18	4	72
Communal land	10	5	1	15
Commercial land	42	42	56	140
Total	102	64	60	226
Wild plants				
State protected areas	-	-	-	-
Communal land	843	66	424	1 334
Commercial land	211	66	75	352
Total	1 054	133	499	1 686
Fish (inland)				
State protected areas	-	-	-	-
Communal land	31	2	62	95
Commercial land	-	-	-	-
Total	31	2	62	95
Total non-tourism use				
State protected areas	50	18	4	72
Communal land	884	73	487	1 444
Commercial land	253	108	131	492
Total	1 187	199	621	2 007

TABLE 4.5. ESTIMATED DIRECT GROSS NATIONAL PRODUCT (GNP) CONTRIBUTED PER KM^2 BY NATURAL RESOURCE USES IN 2009 (N$)

Direct GNP (N$ per km^2, 2009) Region	North West	Central South	North East	Total
Wildlife (other)				
State protected areas	7.11	4.14	3.62	5.79
Communal land (conservancies)	0.60	0.27	0.44	0.44
Commercial land	1.69	5.92	15.78	3.95
Total	**2.11**	**2.31**	**9.62**	**2.75**
Wild plants				
State protected areas	-	-	-	-
Communal land	51.29	4.04	245.13	38.54
Commercial land	8.50	9.37	21.13	9.94
Total	**21.83**	**4.77**	**79.68**	**20.46**
Fish (inland)				
State protected areas	-	-	-	-
Communal land	1.91	0.12	35.71	2.75
Commercial land	-	-	-	-
Total	**0.65**	**0.07**	**9.87**	**1.15**
Total non-tourism use				
State protected areas	7.11	4.14	3.62	5.79
Communal land	53.8	4.43	281.28	41.73
Commercial land	10.19	15.29	36.91	13.89
Total	24.59	7.15	99.17	24.36

4.3 INDIRECT VALUE FROM ECOSYSTEM SERVICES

4.3.1 Carbon sequestration

Carbon sequestration is the removal of carbon dioxide from the atmosphere and storage within the biomass and soils of natural systems. This helps to reduce the potential costs incurred due to climate change. It has been conservatively estimated that climate change in South Africa will carry a cost of about 1 - 2% of Gross Domestic Product by 2050 (possibly up to 6%), due to changes in ecosystem productivity, ecotourism opportunities, disease vectors and agricultural production and due to infrastructural damage, among other effects (Turpie *et al.* 2004). The estimated damages are equivalent to about R80 per ton of carbon emitted, taking into account the fact that carbon contributes about 60% of total greenhouse gas emissions in South Africa (Scholes & van der Merwe 1995, Rowlands 1996).

The sequestration of carbon by ecosystems thus has a positive economic value. For example, in South Africa, Engelbrecht *et al.* (2004) have estimated that 3380TgC could be sequestered in restoration projects within the savanna, karoo and thicket biomes in

South Africa, although their estimates were not spatially explicit and for the savanna biome were based on biomass estimates from the more mesic part of the biome. Estimates were not made for indigenous forests, which contribute only a small proportion of land cover, for fynbos which is probably a poor candidate for carbon sequestration, or grassland which is expected to have very low levels of carbon sequestration. Wetlands do sequester carbon but any benefit is likely to be counterbalanced by the release of CH_4, a greenhouse gas which makes an even greater contribution to climate change (Engelbrecht *et al.* 2004).

Intact ecosystems tend to be in some sort of equilibrium and the net rate of carbon storage is usually understood to be negligible or very low. However loss or gain of vegetation biomass results in decreases or increases of carbon stored and thus kept out of atmospheric circulation. Since the inception of the Kyoto Protocol this service by natural ecosystems has become a valuable commodity (Cihlar 2007). Thus there is also value in the current standing stocks of vegetation, in that their loss would lead to release of CO_2 and a voluntary market has developed for projects that prevent biomass loss.

In this study we used empirical data collected for the compilation of the forest accounts to estimate the standing stocks of carbon in different parts of Namibia. In total, Namibia was estimated to have some 97 million tons of carbon stored in woody biomass (Table 4.6). Based on current prices of carbon (about N$21, J. Arntzen, March 2010, *in litt*.) this is worth an estimated N$28 million per annum. About 15% of the carbon stock is in protected areas (N$4.4million per annum).

TABLE 4.6. ESTIMATED VOLUMES OF WOODY BIOMASS AND TONNES OF CARBON, ACCORDING TO BROAD INTEGRATED REGION AND STATE PROTECTED AREAS, COMMUNAL AND COMMERCIAL LAND NAMIBIA

Volume m^3	**NW**	**CS**	**NE**	**Total**
State	25 851 455	880 650	11 190 744	37 922 849
Communal	98 235 529	2 054 850	19 583 802	119 874 181
Commercial	42 347 145	3 100 300	40 100 166	85 547 611
Total M3	166 434 129	6 035 800	70 874 712	243 344 641
Average $m^3.ha^{-1}$	**5.98**	**0.13**	**11.32**	**5.81**
Carbon tC *	NW	CS	NE	Total
State	10 340 582	352 260	4 476 298	15 169 140
Communal	39 294 212	821 940	7 833 521	47 949 672
Commercial	16 938 858	1 240 120	16 040 066	34 219 045
Total tC	66 573 652	2 414 320	28 349 885	97 337 857

*conversion to tonnes (Odendaal *et al.* 1983) Factor = 0.8; Conversion to Carbon (Birdsley 1996) Factor = 0.5

4.3.2 Water supply and regulation

Namibia is an arid country with limited water resources, with 50% of the population dependent on groundwater and ephemeral rivers (Heyns *et al.* 1998). The role of protected areas in conserving watersheds and water supplies does not appear to have been researched, but based on the flow characteristics, location of protected areas and main dams and river basins (Heyns *et al.* 1998) it would be expected to be minimal for the country as a whole. Locally, in northern areas such as Etosha and Caprivi where larger rivers and substantial wetlands systems do exist, protected areas may act as important areas for water supply to local communities and livelihoods.

4.3.3 Refugia

Protected areas provide an important refuge for a number of species, including several Red Data species that might otherwise be faced with extinction. They also provide a source area for genetic material and biota that are to be found outside of protected areas. This service is very much linked to other services such as provision of raw materials, genetic diversity and cultural services, especially where consumptive use of species, such as mammals or medicinal plants, may depend on reproductive outputs from protected areas. Its value is largely reflected in the national and international funding that is directed at maintaining the area, as discussed below.

Income from wildlife use and nature-based tourism generated by communal areas has been found to be higher for those areas outside and adjacent to established protected areas (Barnes 1995). The link between protected areas and dependence on wildlife in these areas requires further investigation and may also be influenced by the existence of private conservation areas. Nevertheless, in general, areas which generate high values from the use of natural resources, as well as high potential for increase in the value contributed to the national economy, tend to occur outside and directly adjacent to protected areas (Barnes 1995). This was attributed to lower human and livestock densities and higher wildlife populations in these areas (Barnes 1995). The nature of the link between this phenomenon, particularly as they relate to wildlife populations, and protected areas has not been adequately researched, however. Indeed, it is possible that the high value around protected areas may actually be an artefact of the distribution of high value agricultural land (i.e. in areas away from protected areas) and not necessarily linked to the distribution of protected areas themselves (Barnes (1995).

4.4 NON-USE VALUES

Option values are largely derived from the conservation of resources that have the potential to be valuable in future. This value is often associated with genetic diversity, the future potential of which is readily acknowledged but completely unknown. There are many examples of the discovery of new species or genetic material which have turned out to have enormous value in the global pharmaceutical industry. The horticultural industry may also derive substantial benefits from species conserved in Namibia's protected areas. This is already evident in the collection of succulents for propagation from at least one of Namibia's protected areas. Wild genetic resources are also important in the development of new agricultural crops and varieties. Option value cannot be estimated, however. The closest measure available is quasi-option value, which is equal to the amount that society is willing to pay to retain the option of using these resources in future.

Non-use values do not involve any current or future use of protected areas. They comprise a composite of values including existence and bequest values. Non-use values are theoretically reflected in society's willingness to pay to ensure the continued existence of protected areas. Individual values are often reflected in the donations they make or are willing to make to conservation agencies. Global existence value is reflected in the donations that government and non-government organisations make towards the development and maintenance of Namibia's protected areas. In fact, at this level, quasi-option and existence value are very difficult to separate, and are best considered together.

Some studies have been carried out in Namibia on willingness to pay for conservation by visitors linked to nature-based tourism activities (reviewed in Humavindu 2002). Barnes *et al.* (1997), found that visitors were willingness to pay N$144 per person into a conservation trust fund, which worked out to N$28.7 million overall. However, this is the willingness to pay of people that visited wildlife amenities in one particular year, and represents only a fraction of global willingness to pay for the protection of Namibia's biodiversity.

International willingness to pay is at least partly expressed by donor funding which is aimed at biodiversity conservation. International donors have provided varying amounts of funding for environmental projects in Namibia over the years, generally indicating a substantial willingness to pay on the part of the international community for biodiversity conservation and natural resource-linked management and use. Although variable, Namibia's parks typically receive over N$10 million per annum in donor funding for conservation-related projects.

5 CLIMATE CHANGE PREDICTIONS

5.1 INTRODUCTION

Much of work on climate change already done in this region is based on climate scenarios dating from the early 2000's, and the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR3). Climate change scenarios have been updated for the Fourth Assessment Report (IPCC-AR4), and can now be used to estimate the likelihood of the outcomes estimated using older scenarios.

The updated information presented in this section has been used to generate model projections of ecosystem structural change, in turn used to estimate likely ranges of outcomes given the relatively limited set of information available for Namibia. Importantly, we note that IPCC-AR3 model projections used in Midgley *et al.* (2005) are broadly comparable with median projections assessed in AR4, in that a similar level and spatial pattern of warming is consistent, and that a comparable reduction in rainfall is projected.

5.2 OBSERVED TRENDS

5.2.1 Temperature

The following trends have been observed:

- The IPCC (2007) report that between 1961 and 2000, there was an increase in the number of warm spells over southern Africa, and a decrease in the number of extremely cold days.
- Data from between 1950 and 1997 (provided by the NMS) showed that mean temperatures for Windhoek displayed an average increase of 0.023°C per annum over that period (Tarr 1999).
- The 1980s and 1990s were the hottest decades of the 20th century and together with global trends, several records were broken in Namibia for maximum temperatures during the summer of 1997/98. Since then, Warbuton and Schultz (2005) report that numerous new record temperature highs and lows were recorded over South Africa for 2003, 2004 and 2005.
- Potential evaporation, computed as a function of temperature parameters, appears to have increased over most of the interior of southern Africa (Warbuton & Schultz 2005a).
- Midgley *et al.* (2005) examined temperature records from all available long-term weather stations in Namibia and the Northern Cape. This included only 15 stations with durations of between 25 and 60 years. Roughly half the stations showed significant increases in temperature over their recording period, while

none showed a significant decline. The mean decadal increase across all stations during this interval was 0.2°C (s.d. = 0.1°C), an increase that is roughly three times the global mean temperature increase reported for the 20th century.

5.2.2 Precipitation, streamflows and water balance

The following trends have been observed:

- Increased interannual variability in rainfall since 1970 with higher rainfall anomalies and more intense and widespread droughts reported (IPCC 2007).
- Namibia's volumetric rainfall has steadily declined since 1915 (Hutchinson 1998).
- Central Namibia falls directly within the 'drought corridor' – the area between 20 to 25° S that experiences high dry spell frequencies linked to warm ENSO phenomena, or El Niño events. These phenomena have become more frequent and intense since the 1970s (Usman & Reason 2004). Lower flow regimes in major river basins in Namibia and the southern parts of Zambia are also linked to the more frequent occurrence of El Niños (Alemaw & Chaoka 2006).
- Frequency and intensity of extreme hydrological events in the southern African region has increased markedly (Warburton & Schulze 2005)
- Warburton and Schulze (2005a) compare the 1950 - 1969 and 1980 - 1999 timing of the 3 months of highest accumulated winter streamflows and show that (*inter alia*) the Orange River primary catchment displays a shift to 2 months later in the latter period.
- Midgley *et al.* (2005) state that water balance, a composite measure of temperature and rainfall that determines the water available to plants, has shown a significant decline at five of the fifteen weather stations they investigated in Namibia and the northern Cape. No stations showed a significant increase in water balance over this period. These authors also report that a sign of climate change is indicated by the response of populations of *Aloe dichotoma* to apparent trends in recent climate. These responses indicate warming and drying trends in the southern parts of the country over the past 15 to 30 years.

5.2.3 Sea Level Rise

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.* 1992).

5.3 Existing climate projections for Namibia

Despite continuous improvements in climate change science, there is still considerable uncertainty regarding the accurate detection of future global and regional climate change scenarios. These doubts arise from:

- Uncertainty regarding future global GHG emissions;
- Limitations in our understanding of the dynamics of global climatic systems;
- Natural climatic variability displayed in the baseline data;
- Uncertainty pertaining to the CO_2 'fertilisation' effect on plants; and
- Limitations in the downscaling techniques employed to produce RCMs from GCMs – simulations which, at best, produce only a possible evolution of future climate systems.

In Namibia, as in most parts of southern Africa (particularly the semi-arid regions), this situation is exacerbated by a paucity of hydro-meteorological stations and the lack of homogenous, long term, high quality datasets. This hampers the construction of plausible climate models and constrains the reliable assessment of potential scenarios, vulnerability and adaptation to climate change in the country (Warbuton & Schultze 2005; von Maltitz *et al.* 2005; Dirkx *et al.* 2008).

5.3.1 Projected temperature and evaporation changes

In spite of the shortcomings mentioned above, it is predicted with a high degree of certainty that Namibia (and the rest of southern Africa) can expect an increase in temperature and evapo-transpiration at all localities, with the maximum increase in the interior. Warming is likely to be less along the coast than along the escarpment and inland regions. The spatial pattern of change for potential evaporation will also increase as one moves inland. Some projections are as follows.

- South Africa's Country Study on Climate Change (Kiker 1999) made use of three GCMs [2] which indicate an average warming of between 1^{o}C and 3^{o}C by 2050 over southern Africa, with the maximum (up to 4^{o}C) focused on inland regions of aridity and the lowest increases projected for the coastal regions.
- The models considered in GRN (2002) predict that by 2100 the mean annual temperature increase for the central plateau region of Namibia will be between 2 and 6°C above Namibia's 1961-1990 mean temperature.
- Dirkx *et al.* 2008 predict an increase in temperatures by 2065 of between 1°C and 3, 5°C in summer and 1°C to 4°C in winter for Namibia.
- Rising temperatures will cause a corresponding increase in evaporation and it is estimated that for every degree of temperature rise in Namibia, evaporation will increases by 5% (ibid). An increase in potential evapotranspiration of between 4-5 and 15-16% is estimated for Namibia by the 2060's decade is expected (Hulme *et al.* 1996 and Dirkx *et al.* 2008).

[2] These included: an older model (*Genesis*); a coupled ocean-atmosphere model (HadCM2) and a recent current-generation fully coupled ocean-atmosphere model (CSM)

5.3.2 Projected changes in precipitation

Uncertainties in climate forecasts are much greater for rainfall than temperature. Despite this, most GCMs predict that southern Africa and Namibia will become drier, that rainfall variability is likely to increase and that extreme events such as droughts and floods are likely to become more frequent and intense.

Some of the projections for southern Africa and Namibia regarding future precipitation are presented below:

- Hulme *et al.* (1996) suggests decreased rainfall of between 2.5-7.5% and increased rainfall variability of between 5 and 15% by 2050.
- The HadCM2 model used in Kiker *et al.* 1999 indicates (*inter alia*) that summer rainfall could decrease by as much as 15% over most of the Orange-Senqu River basin (including the Lesotho highlands). Winter rainfall is projected to decrease by more than 25% in the northern winter rainfall area (a region that incorporates Namibia's southwestern protected areas) and the lower Orange River and the Fish River basins.
- However, although Hewitson *et al.* (2005a) agree that the winter rainfall season will be shorter in southern parts of Namibia and increased drying can be expected over most of the country (with an increase in intensity of precipitation) they predict a wetter escarpment in the eastern part of South Africa (including Lesotho, the source of the Orange river).
- The changes in climate projected by the HadCM3 model for Namibia's future climate (2050 – 2080) predict that rainfall reductions are expected for the entire country (Midgley *et al.* 2005). These will be more severe in the northwest and central regions than in the southwest and northeast. The projections of rainfall reductions by HADCM3 (between a 10% and 30% reduction relative to the present) tend to be near the extremes projected by six other GCMs3 for summer rainfall, but more extreme than any other GCM for the winter period (~40% reduction relative to the present).

Schultze (2005) illustrates that climate change over southern Africa may result in some marked geographical shifts in the climatic zones such as those defined by Köppen[4]. Some zones will be enlarged (mainly in already hot areas) while others will shrink, both

---

[3] von Maltitz (*et al*, 2005) recommend that in addition to the scenarios created by the HADCM2 and HADCM3 other GCM's are investigated as the former models provide a pessimistic view of future climate for the southern African region.

[4] The Köppen (1931) climate classification system was selected ahead of those by Thornthwaite (1948) or the FAO (1996), because of its universality in usage and its relative simplicity with regard to input data requirements. It is a hierarchical system with up to three levels of detail based on rainfall magnitudes, rainfall seasonality and rainfall concentration, as well as durations above or below threshold temperatures on a monthly basis.

in absolute (km^2) and relative (%) terms when compared with present climatic conditions. The Köppen zones most likely to be reduced include southern Namibia's winter rainfall region incorporating the Succulent Karoo biome (identified by several authors as a 'hotspot' for change).

5.4 INTERPRETATION OF PROJECTIONS FOR THIS STUDY

Because of the high level of uncertainty in projections for future climate in southern Africa, particularly of rainfall change, it seems useful from a policy perspective to estimate the potential ranges of impacts, including high, median and low impacts, by 2050, as it is unlikely that the uncertainty range will be reduced in the near future, and because of the impacts of current levels of climate variability in the region. Variability is likely to dominate the climate signal for at least a few decades until clear climate change signals become evident. Using high resolution spatially downscaled climate information seems of little use in this regard, as it is more important for policy development to estimate the impacts particularly at the median and "tails" of the distribution of possible future climate scenarios. Estimates at the tails of the distribution can provide an assessment of impacts that have a low probability but a high societal relevance if they do occur.

Climate scenarios that are currently generated using General Circulation Models (GCMs) have two main sources of uncertainty that result in a relatively wide range of projections, especially for rainfall futures, for southern Africa in particular. These are 1) the GCM design itself, which varies between the several models used in the IPCC AR4, and 2) the emissions scenarios used to drive the GCMs. The largest source of uncertainty by the middle of this century is due to GCM design, and rather little is due to emissions scenario. Emissions scenario is however an important source of uncertainty and variation for simulations towards the end of the century. As mentioned above, due to the potentially large range of uncertainty in scenarios, it seems of little value to focus on fine spatial scales for climate scenarios and impacts studies, as by far the largest source of uncertainty is at large spatial scale. It is also of limited value to consider a range of emissions scenarios, but rather to focus on understanding the range of GCM variation, and to attempt to represent impacts that might relate to the median and the extremes of that range for policy relevant information.

Unfortunately it is currently difficult to obtain spatially downscaled climate projection data for measures other than rainfall or temperature for southern Africa outside of South Africa for the IPCC AR4 climate projections, especially for the middle of this century. We have thus compared the best available information for the IPCC AR4 generated by GCM's for the year 2100 (median projections of 21 GCMs, driven by the A1B emissions scenario) with the interpolated HADCM3 GCM data used for the previous most comprehensive impacts assessment on Namibia for 2050 (Midgley *et al.* 2005) . Because this comparison (Figure 5.1) shows that the HADCM3 GCM used by Midgley *et* *al.* (2005) represents roughly a median climate future for the 21 AR4 GCMs, climate surfaces representing rainfall and temperature change at the monthly temporal scale for 2050 and 2080 have been created for this project using the HADCM3 GCM (as driven by the A2 scenario). These have been overlaid on a current climate surface that is taken from the recognized and quality-controlled WorldClim data set (Hijmans *et al.* 2005) and used for impact assessments of species-level change.

Comparison of IPCC AR4 scenarios with those used by Midgley *et al* (2005) reveal that the median rainfall change projected for 2100 by the IPCC AR4 (between 5 and 20% reduction) is comparable to the least extreme median rainfall change used by Midgley *et al.* (2005), represented by the HAD CM3 model for 2050, under an A2 emissions scenario. By 2080, this scenario suggests a more extreme rainfall change of between a 10 and 30% reduction. The 2050 scenario used by Midgley *et al.* (2005) shows a relatively spatially uniform rainfall change, with the largest reductions of ~ 20% across the centre of Namibia, with more severe drying suggested in the northwest and on the central coast. This contrasts with the IPCC AR4 spatial pattern that suggests more severe drying of up to 20% in the south, and less drying in the north (between 5 and 10% reductions).

This suggests that rainfall impacts as modeled by Midgley *et al.* (2005) may tend towards the conservative in the south, and be less conservative for the north-west and northern coastal regions. Temperature increases modeled by Midgley *et al.* (2005) agree well with those projected by the IPCC AR4 for 2100, of around 4°C.

In order to assess the uncertainty associated with the latest set of IPCC AR4 climate projections, we present estimates of the seasonal median, 25th and 75th percentile for rainfall and temperature change for Namibia, as estimated by 9 leading GCMs used by the IPCC AR4. The patterns reveal that greatest uncertainty by mid century is associated with summer rainfall in regions with the strongest concentration of rain in summer. While the median rainfall projection for all seasons is for a reduction of up to 20mm/month, the 75th percentile shows between a 10 and 50 mm/month increase in summer rainfall in the northern parts of Namibia, while the 25th percentile includes more than 30 mm/month reduction (Figure 5.2). Rather little uncertainty is associated with winter rainfall. By the end of this century, projection uncertainty is reduced, and the statistical uncertainty hardly includes an increase in rainfall (ie 75th percentile shows small increases in the north, Figure 5.3).

Temperature uncertainties also appear to be the highest for spring and summer months, but the relative quantum is small relative to the rainfall uncertainty, with the range between 25th and 75th percentile being in the order of 0.5°-0.75°C by mid and end-century (Figure 5.4).

One key feature of Namibia's climate is the coastal fog system, which is known to be key for several elements of biodiversity, but there are unfortunately currently no credible projections of change for this system.

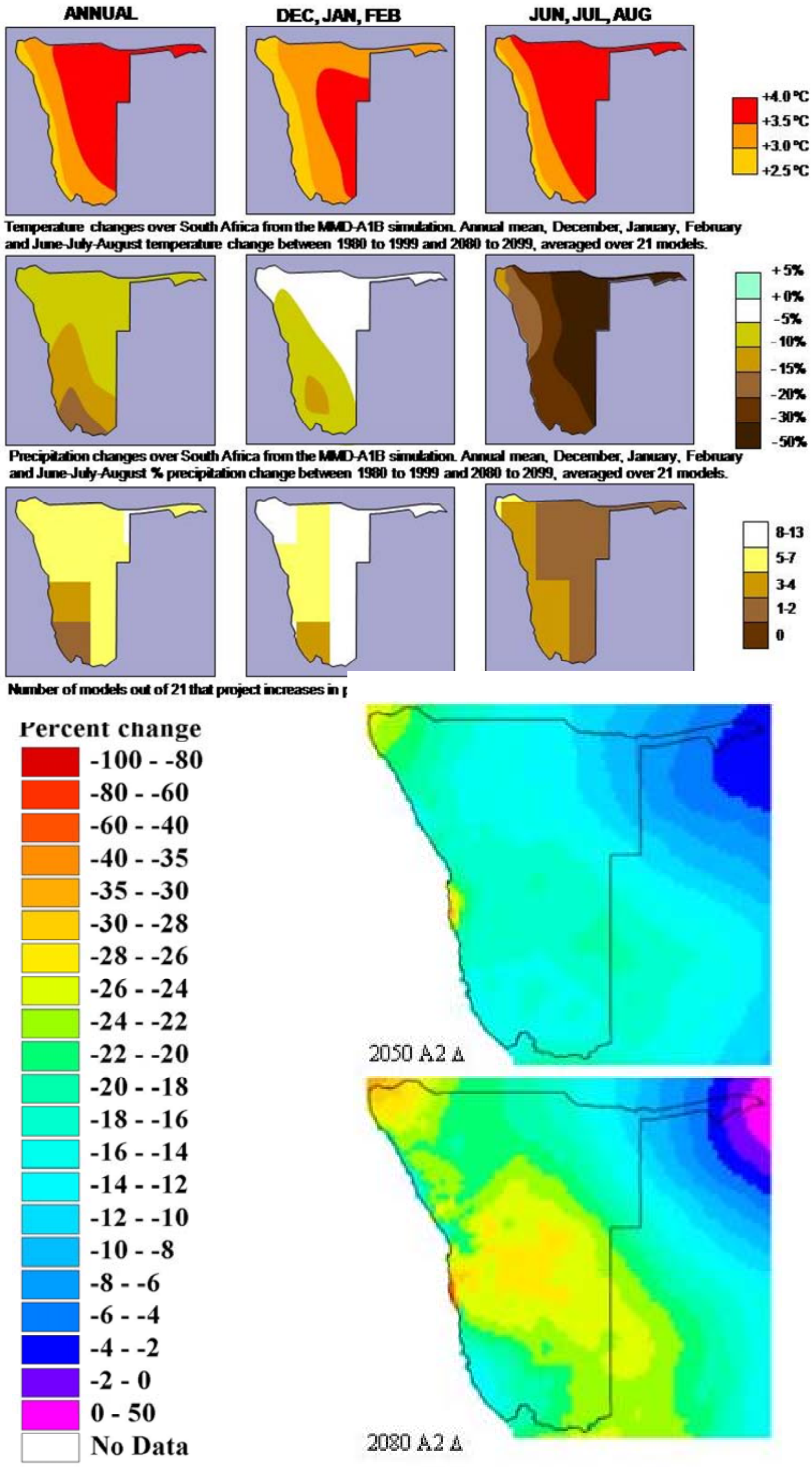


Figure 5.1 Upper panel – Annual, summer and winter changes in temperature and rainfall, and an indication of the uncertainty in rainfall projections for 21 IPCC AR4 GCMs. Lower panel – Annual rainfall changes projected by HAD CM3 as driven by the A2 emissions scenario for 2050 and 2080, interpolated by Midgley *et al*. (2005)

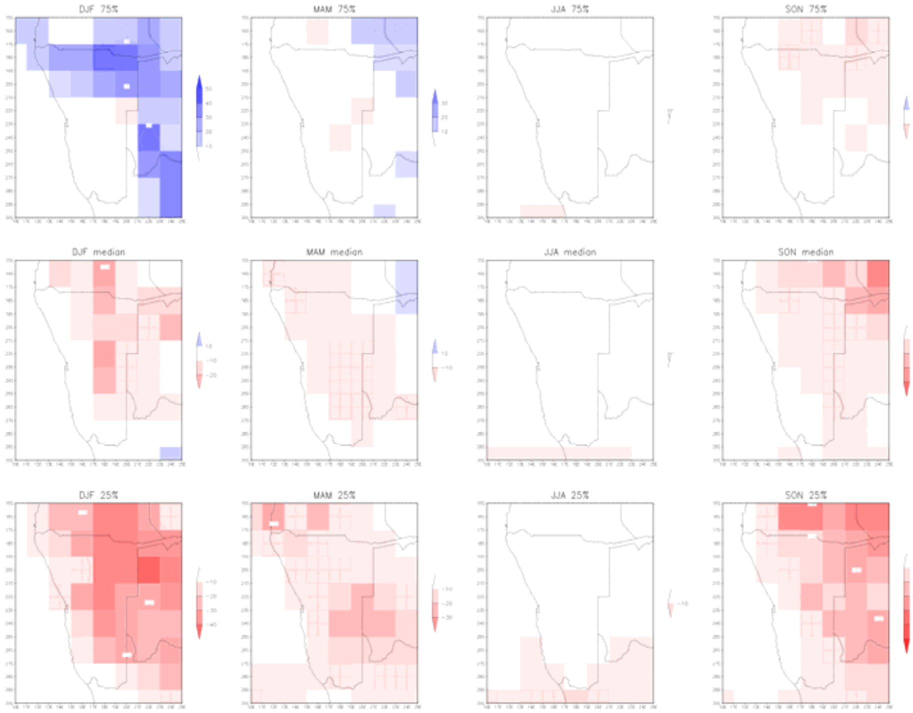


FIGURE 5.2. ANOMALIES (MM/MONTH) SUMMER, AUTUMN, WINTER AND SPRING RAINFALL, FOR 9 IPCC AR4 GCMS. UPPER PANELS ARE 75TH PERCENTILE, MIDDLE PANELS, THE MEDIAN, AND LOWER PANELS THE 25TH PERCENTILE, AS DRIVEN BY THE A2 EMISSIONS SCENARIO FOR MID CENTURY

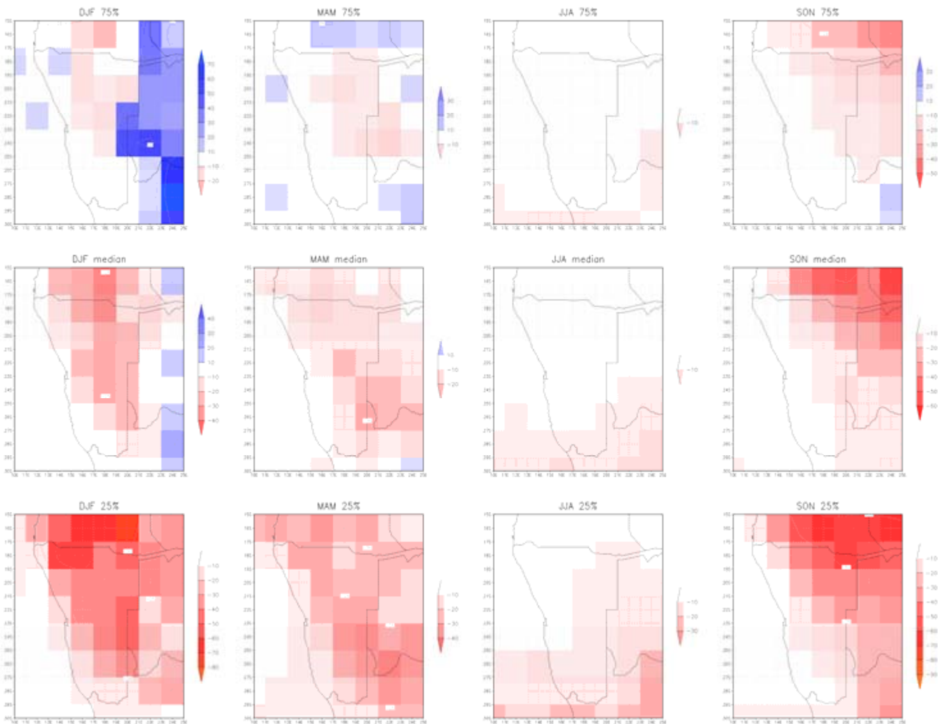


FIGURE 5.3. ANOMALIES (MM/MONTH) SUMMER, AUTUMN, WINTER AND SPRING RAINFALL, FOR 9 IPCC AR4 GCMS. UPPER PANELS ARE 75TH PERCENTILE, MIDDLE PANELS, THE MEDIAN, AND LOWER PANELS THE 25TH PERCENTILE, AS DRIVEN BY THE A2 EMISSIONS SCENARIO FOR END CENTURY

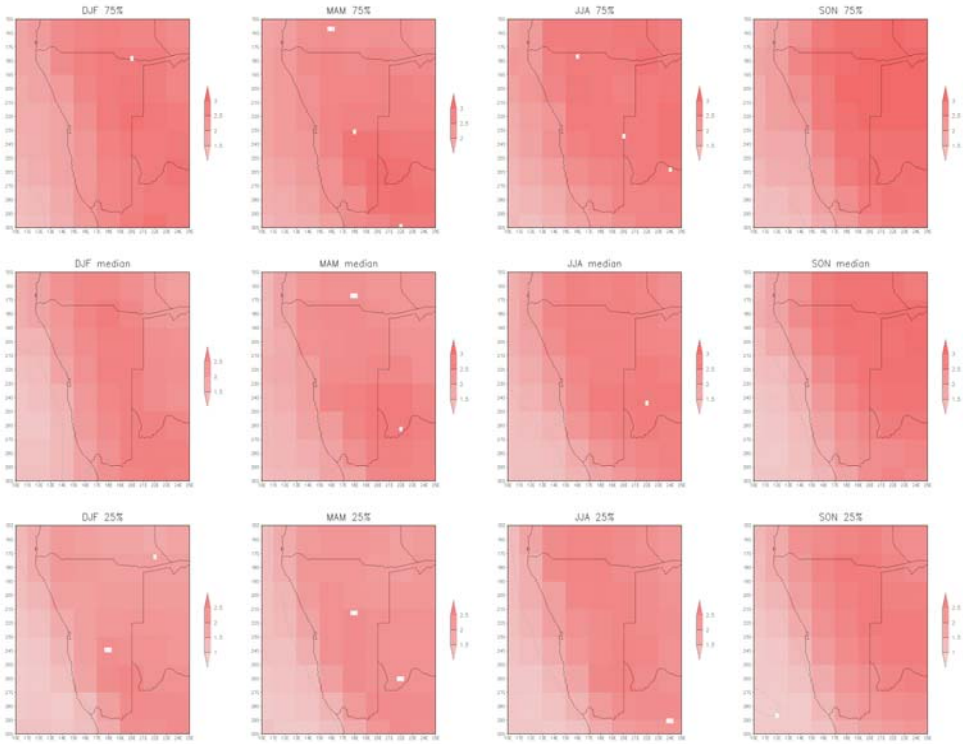


FIGURE 5.4 ANOMALIES (°C) SUMMER, AUTUMN, WINTER AND SPRING SURFACE AIR TEMPERATURE, FOR 9 IPCC AR4 GCMS. UPPER PANELS ARE 75TH PERCENTILE, MIDDLE PANELS, THE MEDIAN, AND LOWER PANELS THE 25TH PERCENTILE, AS DRIVEN BY THE A2 EMISSIONS SCENARIO FOR MID CENTURY

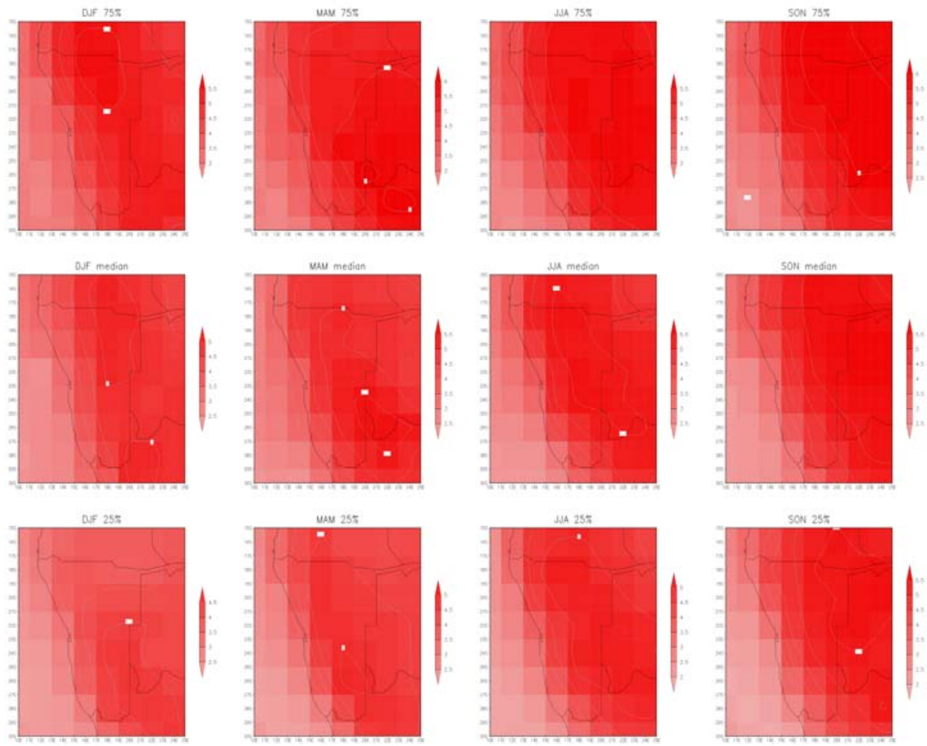


FIGURE 5.5 ANOMALIES (°C) SUMMER, AUTUMN, WINTER AND SPRING SURFACE AIR TEMPERATURE, FOR 9 IPCC AR4 GCMS. UPPER PANELS ARE 75TH PERCENTILE, MIDDLE PANELS, THE MEDIAN, AND LOWER PANELS THE 25TH PERCENTILE, AS DRIVEN BY THE A2 EMISSIONS SCENARIO FOR END CENTURY

6 DIRECT IMPACTS ON ECOSYSTEMS AND BIODIVERSITY

6.1 INTRODUCTION

This section draws together key information relating to projected anthropogenic climate change and a subset of impacts on Namibia. It makes use of already published material and selected new work to estimate the likely range of impacts on the following dependent variables: Vegetation structure, biomass and productivity (de Wit and Stankiewicz 2006, Midgley *et al*. 2005, Scheiter & Higgins 2009), plant diversity (Midgley *et al.* 2005), and surface water resources (de Wit & Stankiewicz 2006).

The Intergovernmental Panel on Climate Change has identified this sub-region as one of the most vulnerable to anticipated climate change (IPCC 2007). Namibia, located within the most arid part of southern Africa, where drought is endemic and where great demand is placed upon natural resources[5], is considered to be particularly sensitive to the impacts of climate change.

The following studies have been carried out in Namibia:-

- A desktop report conducted by Tarr (1999), which highlights the potential effects of climate change on Namibia's water, agriculture, fisheries, ecosystems and biodiversity, human and livestock health, and energy sectors.
- Namibia's Initial National Communication to the United Framework Convention on Climate Change (GRN 2002)
- An assessment by Midgley *et al.* (2005), which focuses on the potential impacts of climate change on Namibia's floristic diversity, ecosystem structure and functioning;
- An analysis by Reid *et al.* (2007) on the impact of climate change on the agricultural and fisheries sectors in Namibia and how it will affect the GDP and Namibian society; and
- A study conducted by Dirkx *et al.* (2008), which addresses the vulnerability and adaptation of Namibia's wetlands, water resources and agricultural sector to climate change, with particular focus on the Caprivi and Karas regions.

Despite the paucity of work conducted with Namibia as the primary focus, extensive research has been done on South Africa's responses to climate change. Some of these studies have relevance to the SADC region as a whole and/or to Namibia (in particular southern Namibia and the Orange River Basin). These documents include:-

[5] In 2003 agriculture, fisheries and mining accounted for about 30 per cent of Namibia's total GDP (Lange 2003).

- Hulme *et al.* (1996) Climate change and southern Africa: An exploration of some potential impacts and implications in the SADC Region;
- South Africa's Country Study on Climate Change (SACSCC; Kiker 1999);
- A desktop study by Turpie *et al.* (2002), which discuss the potential economic impacts of climate change in South Africa;
- The numerous research papers gathered in Schultze (2005), which focus on potential climate change scenarios, impacts, vulnerabilities and adaptations of the water resource sector in southern Africa; and
- von Maltitz *et al.* (2005), a CSIR research document that investigates the impacts and adaptations to climate change by the biodiversity sector in South Africa.

This section consolidates and builds upon the abovementioned studies. It needs to be stressed, however, that predictions on the ecological responses to climate change are based on global climate change models that are broad in scale and highly variable in their predictions, depending on the assumptions made. Furthermore, general understanding of the links between climatic parameters and ecological responses is still extremely poor. Thus it must be recognized that accurate predictions cannot be expected.

6.2 Sea-level rise

Tide gauge records from Lüderitz and other localities on the west coast of southern Africa over the last 30 years have revealed an estimated sea-level rise that is comparable with these global measurements (Hughes *et al.* 1992). The IS92a greenhouse gas emissions scenario estimates a continued 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 (UNEP 1996).

The following responses to sea-level rise are expected (*ibid*):-

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

Namibia's few coastal towns and settlements are important centres for the country's fishing, tourism, guano, salt and mariculture industries. Coastal wetlands, including Sandwich Harbour, Walvis Bay lagoon and the Orange River mouth provide nursery areas for some commercially important fish species (H.Holtzhausen, *pers comm*.) and are important feeding grounds for large flocks of palaearctic 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 communities include rapid urbanisation, growing unemployment, housing shortages, growing waste management issues, and increasing pollution of inshore waters in the vicinity of the Walvis Bay and Lüderitz harbours (Tarr 1999). Some of these problems will be compounded by sea-level rise and other effects of global warming.

In 1991 a preliminary study on the vulnerability of Walvis Bay to sea-level rise (Hughes *et al.* 1992) ascertained that this low-lying town is likely to experience impacts of first order magnitude to sea-level rise. The main threats are likely to result from increased incidence of flooding and inundation of the lowest-lying areas of the town (affected sites include some schools and the cemetery) and increased vulnerability to the effects of higher storm-induced coastal water levels *viz.* potential losses to land, damage to property, infrastructure and tourism/recreation potential.

6.3 Change in freshwater flows

Attempting to quantify climate change impacts on runoff, streamflow and hydrology in southern Africa is complicated by the fact that most river systems and their catchment areas are already impacted by anthropogenic activities. Their spontaneous regulatory functions have been disrupted through deforestation, erosion, the draining of wetlands and/or dam construction and the intensification of water extraction.

Because of high evaporation rates, it is estimated that only 2% of the rain that falls in Namibia is available as runoff and only 1% is available to recharge groundwater (Heyns *et al.* 1998). Furthermore, Namibia's sparse rainfall displays a high degree of temporal and spatial variability. This leads to a corresponding high variability in runoff, soil moisture and stream flow. Thus, even in the absence of climate change, water demand in Namibia (dictated by the expansion of irrigation and mining projects as well as the domestic demands of a rapidly expanding, urbanising population), is expected to surpass the installed abstraction capacity by 2015 (in Dirkx *et al.* 2008).

Kiker (1999) modified and updated the *ACRU* hydrological modelling system to determine potential changes in runoff and streamflow together with the HadCM2S GCM. From this study it may be concluded that (*inter alia*):

- The western catchment areas of South Africa could experience a 10% decrease in mean runoff by the year 2015; and
- Significant decreases (10 – 20%) in stream flow of the Orange River will result in a 12 – 16% decrease in outflow at the Orange River mouth by 2050.

Schultze *et al.* (2005a) considered a 1975 - 2005 'present' and a 2070 - 2100 'future' climate scenario. They show that increasing temperatures and projected climate change in southern Africa will result in:

- Projected increases in potential evaporation by 10 - 20%. This increase will be accompanied by dam evaporation losses and increased irrigation demands.
- Soils becoming drier more often. This will result in reduced runoff per mm rainfall, agricultural land use changes, ecological changes, reduced crop yields and higher irrigation demands.
- Fewer, but more intense rainfall events which may result in more runoff (but also increasing erosion/negative impacts on seed germination/poor aquifer recharge)
- Shifts in the distribution of streamflows resulting in changes to the ecological reserve and operating reservoirs.

These authors identified several potential hotspots where anticipated climate change could result in severe water resource management implications. One hotspot is the present winter rainfall region which incorporates the lower Orange River basin.

Dirkx *et al.* (2008) state that:

- A reduction of 10-20% in rainfall in Angola and Zambia by 2045-2065 is expected to lead to a reduction in runoff and drainage of the Zambezi, Okavango, Cuvelai and Kunene rivers by +/- 25%;
- Expected impacts on run-off, peak flows, and sustainable dam yields for the Fish River basin suggest that runoff may increase in the far south of the country;
- Floodplains in the Caprivi and oshanas in the Cuvelai may be particularly vulnerable to the effects of climate change as it is likely that smaller areas will be inundated, and that they will dry out more rapidly due to increased evaporation. The Okavango Delta may be strongly affected in similar ways and may shift into a seasonal river; and
- Due to ambiguities in measuring changes to rainfall and runoff in Namibia it is difficult to deduce the implications for groundwater recharge in the Caprivi, the Omaruru, Kuiseb and southern regions of the country. Some of the literature these authors quote suggests that groundwater recharge may suffer a reduction of 30-70% across Namibia; an exception could be the recharge of alluvial aquifers that have their origins in central areas of Namibia, where increasing late summer convective rainfall may be expected by the mid 21st century.

In conclusion, the major constraints which currently challenge national and regional water resources will be exacerbated as a result of climate change. These include:

- Escalating financial costs of supplying adequate water to agriculture (mainly crop irrigation), mining/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;

- 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;
- Increasing water demand and water pollution by irrigation schemes (see following section on Agriculture); and
- An increase in transboundary issues with upstream users (including Lesotho and South Africa in the case of the Orange River Basin and Angola and Zamibia in the case of the northern perennial rivers) and downstream users (Botswana in the case of the Okavango) that share Namibia's perennial rivers.

6.4 Changes in fire risk

6.4.1 Introduction

Fire is one of the most widespread ecological disturbance factors in the world. While lightning-ignited fires have always played a major role in African savannas, it is thought that the vast majority of the veld fires that we see today are caused by anthropogenic actions. A long history of repeated burning has shaped the landscapes of fire-prone parts of the world, and is responsible for the maintenance of particular vegetation types such as savanna.

Veld fire generally does not have a direct lasting effect on biodiversity. It does however have the ability to bring about quite dramatic changes to the structure of vegetation communities, which has profound implications for biodiversity. Furthermore, given the right circumstances, fire has the ability to suspend plant succession which would otherwise tend to progress to a climatic climax community. As a general rule, and given the right climatic conditions, removing fire from the landscape will lead to thicket formation dominated by small trees such as Black thorn *Acacia mellifera* and Sickle bush *Dichrostachys cinerea* in the lower rainfall areas of Namibia, while succession in the higher rainfall areas will proceed to thickets formed by dense stands of species that have the potential to grow tall but, having escaped the fire trap, struggle to find sufficient nutrients, water and light in a suddenly overcrowded environment. Examples of rapid thicket formation in the semi-arid zone abound in the freehold farming areas, while a striking example of fire exclusion in the higher rainfall areas of the country is the impenetrable thicket at Sachinga cattle breeding scheme in east Caprivi.

6.4.2 The current state of affairs

The following sections are based on the analysis of data derived from the MODIS instrument onboard NASA's[6] Aqua and Terra satellites, as well as from the AVHRR instrument onboard NOAA's[7] POES[8] series of satellites. Active fire data spans a 6 year period from 2003 to 2008, while burned area data covers the period from 2000 to 2008.

An average of 43 615 km^2 of land (5% of Namibia) burns annually. These fires are all but confined to the savanna biome. This is not an unusual situation – tropical savannas around the world are particularly fire prone. They owe their existence to repeated burning, and in return provide ideal conditions for fires. Although veld fires occur in some part of the savanna every year, relatively small areas are subjected to annual burning (Figure 6.1). These tend to be in protected areas, with Mudumu National Park being particularly fire prone. Actual fire events across much of the area are confined to less than 10 days per year, but a few areas in the north-east may experience fires for as many as 60 days per year (Figure 6.2).

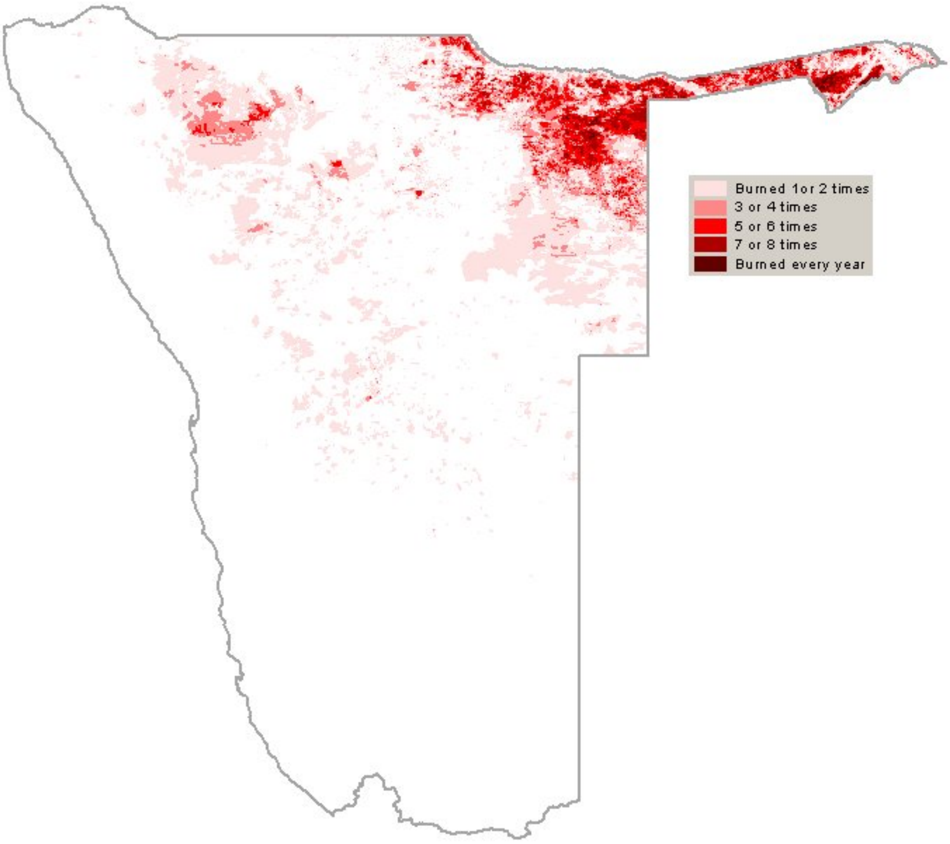


FIGURE 6.1. FIRE FREQUENCY OVER A 9 YEAR PERIOD

[6] NASA: National Aeronautics and Space Agency of the U.S.A.
[7] NOAA: National Oceanographic and Atmospheric Agency of the U.S.A.
[8] POES: Polar Orbiting Environmental Satellite

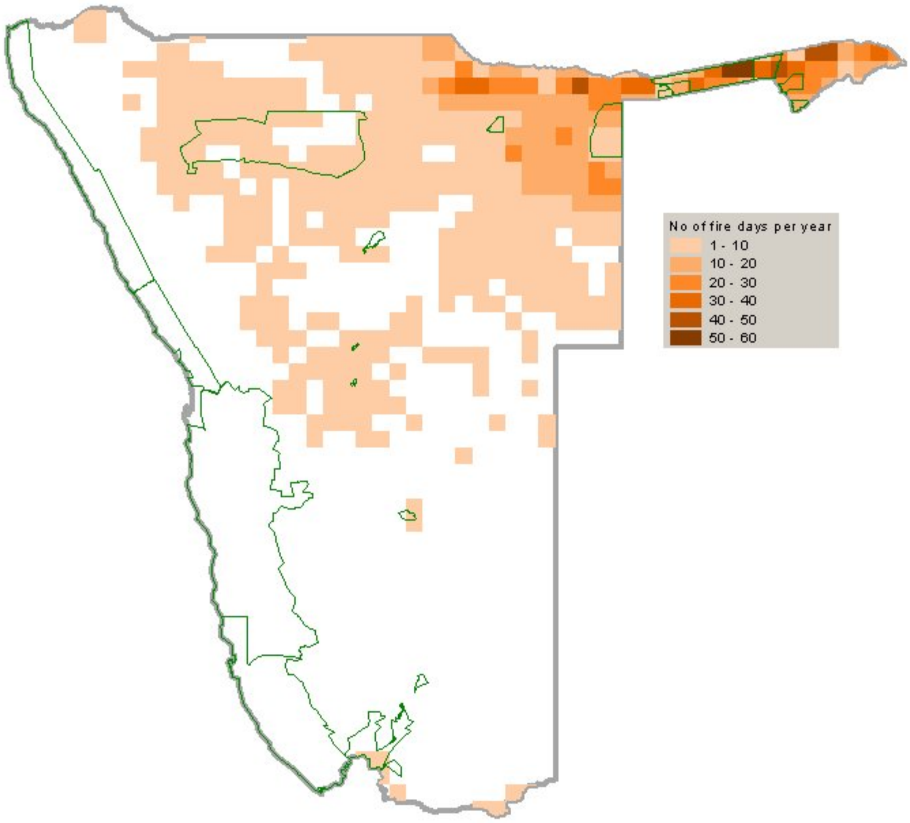


FIGURE 6.2. THE NUMBER OF DAYS ON WHICH FIRES WERE RECORDED, PER QUARTER DEGREE SQUARE

Fires are confined to the dry season, with most of the fires occurring towards the end of the hot dry season (Figure 6.3). September fires account for half of the total area burned in a particular year.

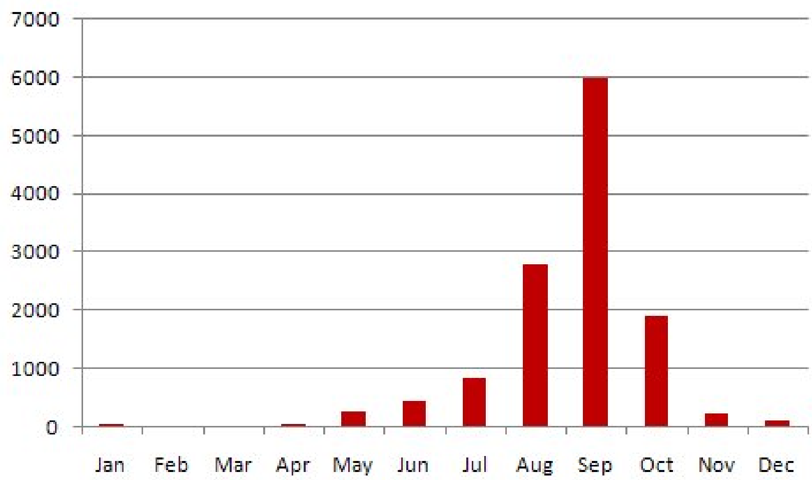


FIGURE 6.3. MONTHLY DISTRIBUTION OF THE NUMBER OF ACTIVE FIRES RECORDED PER YEAR

6.4.3 Trends in fire frequency and impacts of burning practices

The period for which quantitative fire data is available is not long enough for meaningful trends to emerge. No part of Namibia is currently subjected to a fire return period of less than one year. In other words, the highest fire frequency for any area is annual. It is unlikely that this will change as long as annual rainfall remains unimodal. Since the actual frequency cannot increase, the question of trends requires an answer expressed in spatial rather than temporal terms, i.e. whether the spatial extent of the area that is subjected to annual burning is increasing or not . The current dataset does not even span one decade, and many decades would be required to derive a trend.

Fire frequency may be an important measure of fire impact on some ecosystems, but this is not the case in Namibia. The notion that fires are now more extensive and or more frequent than in the past is a popular one, but is not supported by scientific evidence. There is however no doubt that the current burning practice in Namibia is causing large scale structural vegetation changes. This is indeed manifest in the death of many large trees and an increase in shrub density. The age of these shrubs point to a relatively recent shift in the fire regime that maintained the dry woodlands that are a feature of the north-east.

6.4.4 Impact of climate change

Current climate change models for Namibia generally predict a decrease in rainfall or an increase in rainfall variability or both. There is an inverse relationship between rainfall and fire frequency. In other words, arid areas burn infrequently, while mesic areas burn often. This is illustrated by Figure 6.1, where the arid western areas burned less frequently than the higher rainfall areas in the north-east. At the extremes of the climatic scale, fires are absent because the rainfall is either too low to provide sufficient fuel loads, or the rainfall is so high that there is insufficient time for the biomass to cure. Neither of these two scenarios are predicted for the areas currently affected by fire in Namibia.

The fire-affected areas presently lie above the 250 mm rainfall isohyet. Under the decreasing rainfall scenario, this isohyet is expected to shift eastwards. This could cause a commensurate eastward shift in fire frequency. As a result, the western parts of the Etosha National Park may experience fires once in twenty years or not at all. Under an increasing rainfall variability scenario, the future is much more difficult to predict, and fires may occur in unusual areas with unpredictable frequency. It only takes one good rainy season for burned areas to almost double in size. Conversely, widespread burning in one year, followed by an average or below average rainy season can reduce the burned area dramatically, as was the case in 2008. This increase in burned area during 2007 was caused by a series of fires that burned in north-central Omaheke region, which has s a very low fire frequency.

6.5 Impacts on marine habitats and biodiversity

In response to the many interactive effects of global warming on Namibia's marine environment (including increased sea surface temperature and sea-level rise), the following outcomes are possible:

- Changes in tidal ranges are possible as wind and pressure regimes become affected by a weakening of the temperature gradient between the equator and the poles (Lombard 1998);
- Increased sandy beach erosion and altered sedimentation of coastal lagoons may occur (Tarr 1999);
- Namibia's offshore islands, important roosting and breeding sites for several species of sea and shorebirds, could experience increased inundation and vulnerability to storm events (ibid);
- 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 (ibid);
- Slackening off of the south-westerly winds or prolonged periods of hot east wind would be detrimental to the local survival of Cape fur seal pups. In addition, all top predators of the Benguela system (fish, seabirds and mammals) could be affected by altered food supplies due to the changes in primary productivity that may accompany altered wind regimes, upwelling frequency and strength (JP Roux pers. comm. 1999); and
- The possibility of fewer fog days along the coast will threaten the survival of many unique, endemic coastal plant species (including *Welwitschia mirabilis*) that are well adapted to current conditions within the fog belt (Tarr 1999). Midgely *et al.* (2005) report that GCMs are currently unable to simulate details of incidence of coastal fog. Thus, the scenarios they use represent a conservative change for coastal regions in central and southern Namibia, because they are forced to assume that current patterns of fog incidence will not be affected by climate change.

Namibia's marine fishery is an important foreign exchange earner and significant employment generator. It is dependent on the vagaries of the BCLME – an inherently unstable ecosystem that displays continuous variation. Climatic factors are responsible for triggering periodic extreme, anomalous events within the BCLME. These include red tides, sulphur eruptions, periods of deep water anoxia and episodic Benguela Niños, all of which are capable of having a dramatic effect on primary production and the availability of fish stocks. In addition to the natural climatic variability that drive these changes, threats to the productivity of Namibia's marine fisheries sector include the over exploitation of stocks and increasing inshore pollution.

Although new generation GCM's, like the Hadley Centre's coupled Atmosphere-Ocean GCMs can be used to detect some of the direct effects of climate change on marine systems (for example, sea-level rise and increases in sea surface temperature), these models are unable to provide detailed information on changes to ocean currents, wind regimes and upwelling processes - the very factors that drive the BCLME and determine the productivity of Namibia's marine fisheries sector. Furthermore, the lack of appropriate research on the functioning of the Benguela ecosystem itself limits the ability to predict the many interactive effects of environmental 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 not easy. 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 expected outcomes of global warming (Tarr 1999).

Sea surface temperatures (SST) affects the transfer of heat energy between the sea and the atmosphere and are therefore able to influence wind speed and strength as well as the cloudiness and radiation (energy) balance of the atmosphere (NMS 1998). Global warming will cause SST to increase together with air temperatures, although not as rapidly or to the same degree. By the year 2050, these changes are likely to have a profound effect on the physical, biological and biogeochemical characteristics of the world's oceans, and 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 state to another (in Lombard 1998).

Increased SST and higher levels of atmospheric/oceanic CO_2 will enhance the photosynthetic rate of phytoplankton and other marine plants. However, this improved primary productivity 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 Benguela's 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 productivity dramatically (Brown & Cochrane 1991) – a situation that would benefit pelagic fish stocks.

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).

Marine species most sensitive to climate change include those that have been heavily exploited. Thus, in order to help adapt to future climate change, 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 favour 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 (Tarr 1999).

6.6 Impacts on wetlands and their biodiversity

Wetlands (including coastal lagoons and seasonal oshanas), and their associated fauna and flora, are currently identified as Namibia's most threatened ecosystems (Barnard 1998). Most wetlands are underprotected and highly vulnerable to increasing pollution, over abstraction and devegetation (Barnard *et al.* 1998). The added stress of climate change is likely to further exacerbate the ability of Namibia's wetlands to provide valuable ecological services such as water retention, purification and flood attenuation (Dirkx *et al.* 2008). In addition, the mouths of the Kunene and Orange rivers (both awarded Ramsar site status) are likely to suffer severe ecological impacts as a result of reduced flow regimes and overabstraction in future decades.

6.7 Impacts on terrestrial habitats and productivity

6.7.1 Introduction

Climate is a primary determinant of the nature and functioning of ecosystems. Changes in climate result in several responses over a broad range of temporal and spatial scales. These range from the 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 make-up of populations over millennia.

Areas in Namibia that are particularly vulnerable to climate change include the western escarpment (which separates the arid desert from the semi-arid savannas), and the southwestern Succulent Karoo – both important centres endemism. The latter is considered to be one of the world's 25 top 'global biodiversity hotspots' and is likely to suffer considerable numbers of local extinctions by 2050. Existing studies suggest that

Namibia's vegetation is likely to shift in spatial dominance from Grassy Savanna to Desert and Arid Shrubland by 2080 (Midgley *et al.* 2005)[9].

Midgley *et al.* (2005) also suggest a reduction in ground cover and reduced Net Primary Productivity (NPP) throughout much of the country by 2050 (exacerbated by 2080), a situation that will have important implications for the faunal component of Namibia's ecosystems.

Increased concentrations of CO_2 and rising temperatures alone are capable of causing considerable changes to the primary productivity of ecosystems. Although the responses of individual plant species to elevated CO_2 are difficult to measure, a sustained increase in ambient temperature is capable of causing significant changes in species distribution, composition and migration (Tarr 1999).

Midgley *et al.* (2005) acknowledge that the impact of the CO_2 fertilization effect introduces some uncertainty in their projections, particularly in the northern and north eastern Kalahari region. They state that the impacts of rising atmospheric CO_2 could increase primary productivity in certain plants, thus ameliorating some of the expected vegetation responses to changing climates. Elevated CO_2 could enhance the reduced dominance of Grassy Savanna by 2080 (by exacerbating the increase in C3-dominated vegetation types, Woody Savanna, Mixed Grassland, and C3 Grassland/Shrubland). This suggests that bush encroachment problems in these regions may become intensified. They determine that arid vegetation types could increase in cover by almost 20% by 2050, and up to 43% by 2080 in the absence of a CO_2 fertilization effect, but with CO_2 fertilization modeled, the expansion of desert by 2080 is reduced from 43% to just under 30%.

While it is accepted that bioclimatic niche models have many shortcomings, the results emanating from the Midgely *et al.* (2005) study indicate an appreciable vulnerability of Namibian biodiversity as a whole to projected anthropogenic climate change, and the need to ensure pressure on the adaptive capacity of conservation planning in this country over the next few decades.

6.7.2 Changes in primary production

Based on the observed current and future predicted PP the national total PP is predicted to decrease by 4.5%. For the conservation network the decrease is similar and predicted to be 4.4%. In arid areas (<500-600mm rain per annum) PP is directly correlated with the numbers of livestock or game that can be kept on the land.

[9] This research based on the HADCM3 GCM employed dynamic global vegetation modelling (DGVM) tools to simulate changes in vegetation structure and function, and statistical modelling approaches to develop bioclimatic niche models (BNM) for 834 plant species

Therefore it is possible to quantify in monetary terms the impact of CC on industries dependent on primary production (stock and game farming, protected areas, fuel wood harvesting) as well as the rural and national economies.

However, change is not equal across the country (Figures 6.4, 6.5). Summer rainfall areas are expected to increase by as much as 30% especially high-lying areas such as the Kaokoveld (northern escarpment) and central plateau. In contrast, winter and winter/summer ecotone rainfall areas in the south are expected to decrease by as much as 40% particularly in the Central/southern Namib, Succulent Karoo and Nama Karoo.

6.7.3 Changes in vegetation structure

In this study we have used the dynamic global vegetation model approach as described in a recently published article (Scheiter & Higgins 2009) that greatly improves previous models of this sort for the African continent. Briefly, the modelling approach uses climate and soils information to predict the evolving relative success of a few main plant functional types, competing for light, nutrient and water resources, and responding to wildfires that are internally generated by the model. The model has a strong physiological basis, including calculations of carbon uptake via photosynthesis (dependent on light, water, temperature and nutrient availability), respiration and growth, carbon allocation to above and below ground parts, decomposition and wildfire. The model has been shown to simulate African savanna and grassland vegetation structure and function to a credible degree (Scheiter & Higgins 2009). In these simulations, the model was driven by the HADCM3 GCM.

The model suggests a reduction in the density of woody plants less than 2m tall (trees and shrubs) over much of Namibia by the end of this century, especially in northern Namibia and the central highlands (Figure 6.6). By contrast, the density of tall trees (> 2m tall) is projected to increase substantively in places in the north of Namibia, and in the southern/central region (Figure 6.7). Woody plant biomass is projected to decrease over much of Namibia, with few exceptions (Figure 6.8). Grass standing live biomass is projected to show a reduction over much of Namibia, with the exception of the Omaheke, Otjozundjupa, Oshikoto and Kavango regions (Figure 6.9).

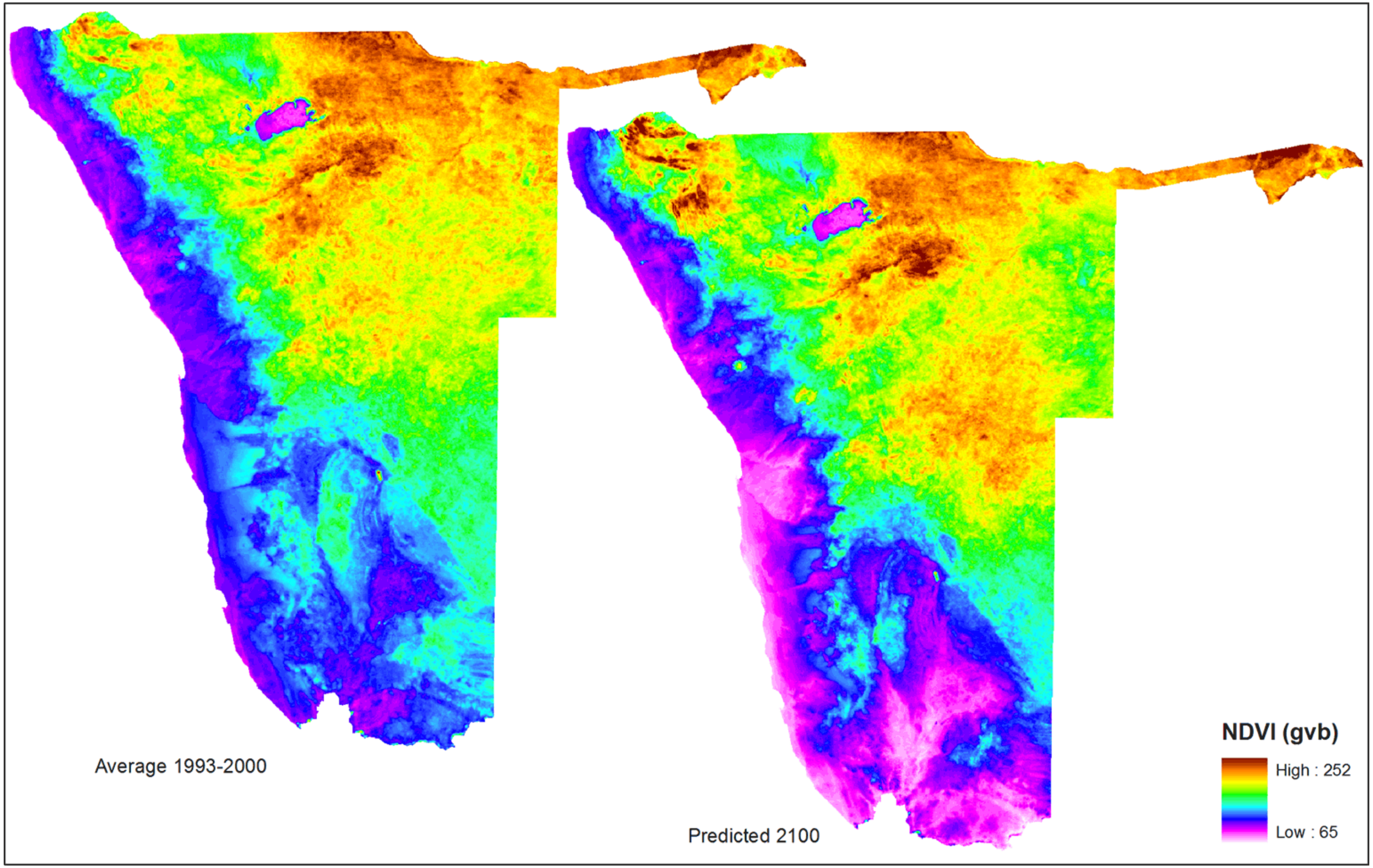


Figure 6.4. Predicted changes in plant primary production (based on modelled PP) between 2000 and 2080

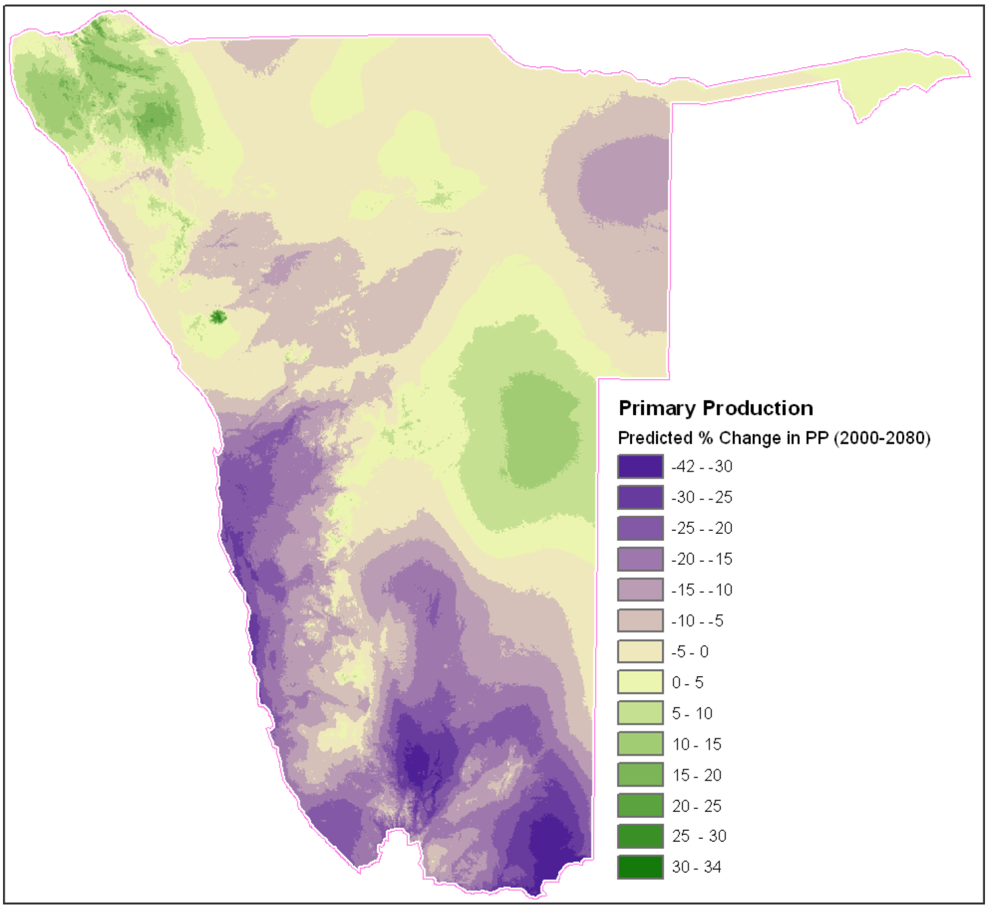


FIGURE 6.5. THE PREDICTED PERCENTAGE CHANGE IN PRIMARY PRODUCTION BETWEEN 2000 AND 2080

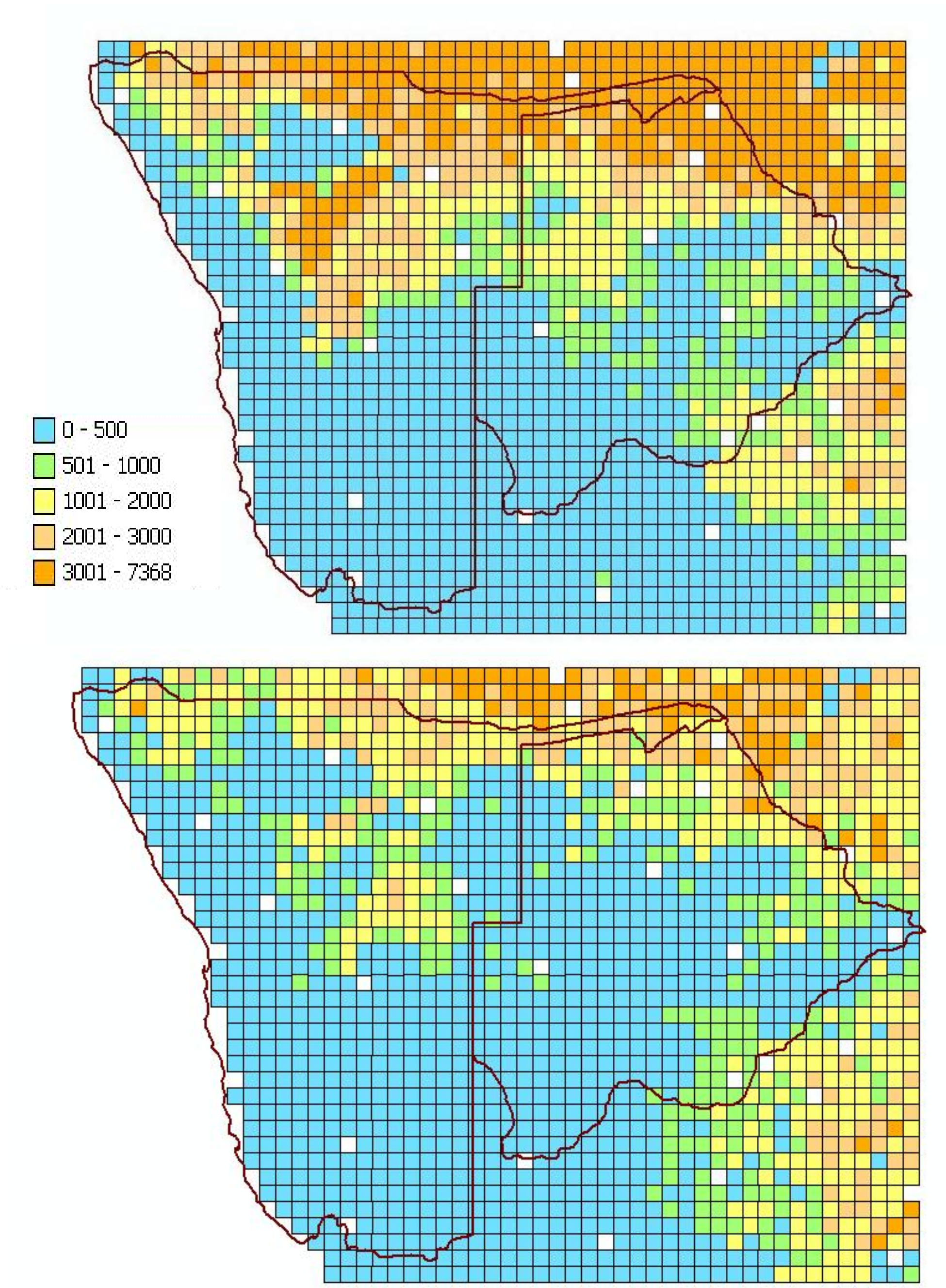


Figure 6.6. Density (number per hectare) of woody plants less than 2m tall in 2009 (top panel) and 2100 (lower panel)

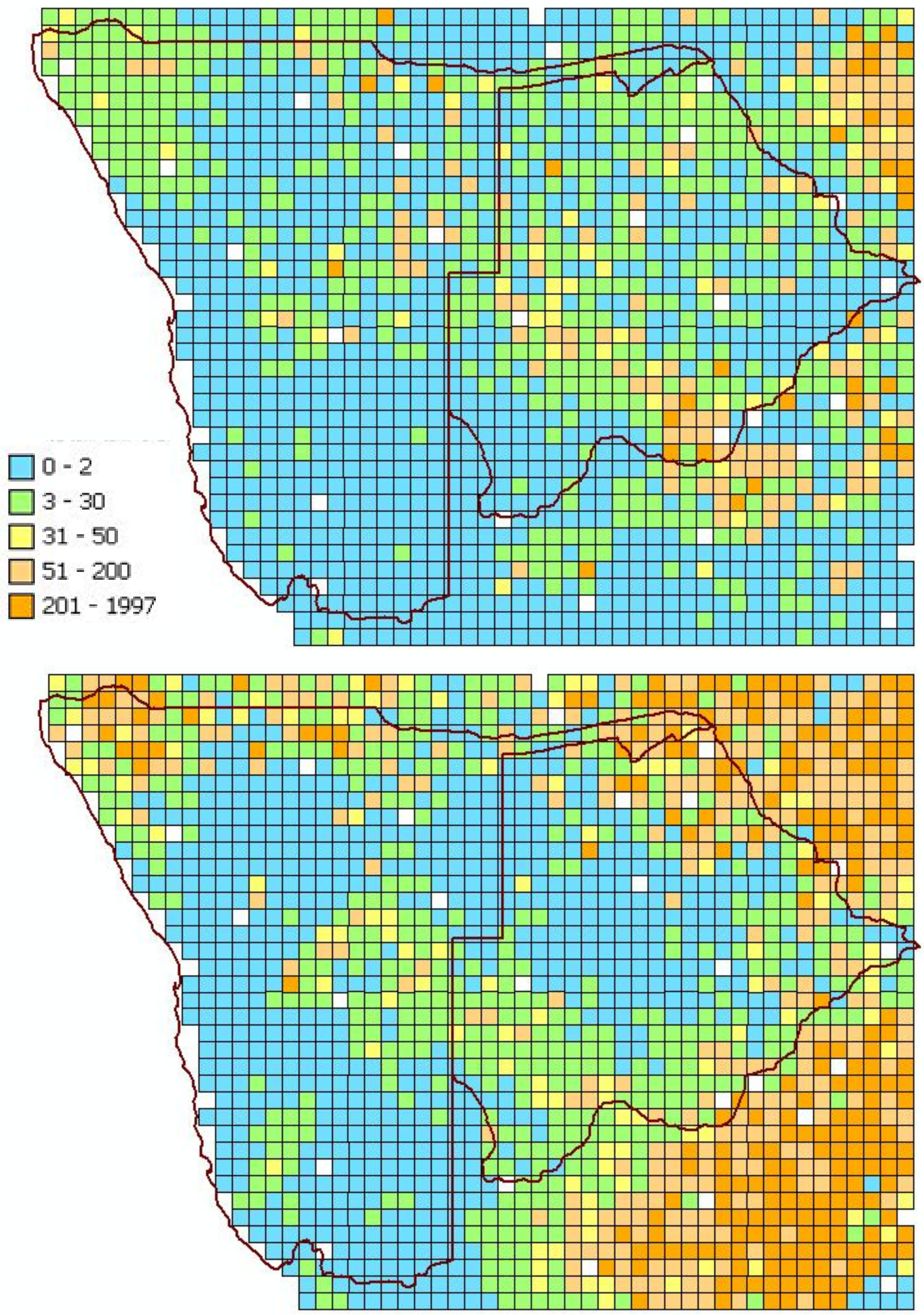


Figure 6.7. Density (number per hectare) of woody plants greater than 2m tall in 2009 (top panel) and 2100 (lower panel)

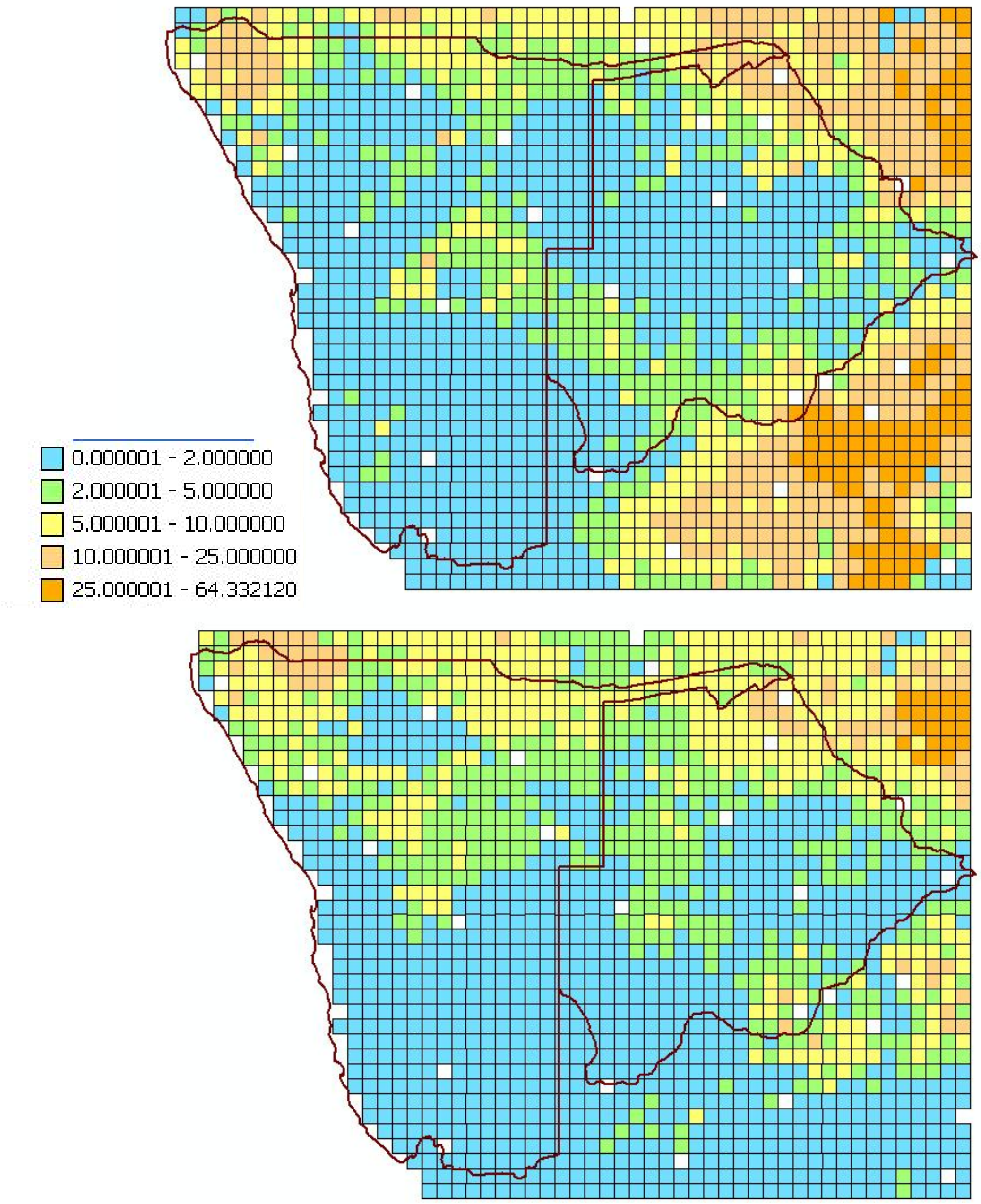


FIGURE 6.8. WOODY PLANT BIOMASS (TON PER HECTARE) IN 2009 (TOP PANEL) AND 2100 (LOWER PANEL).

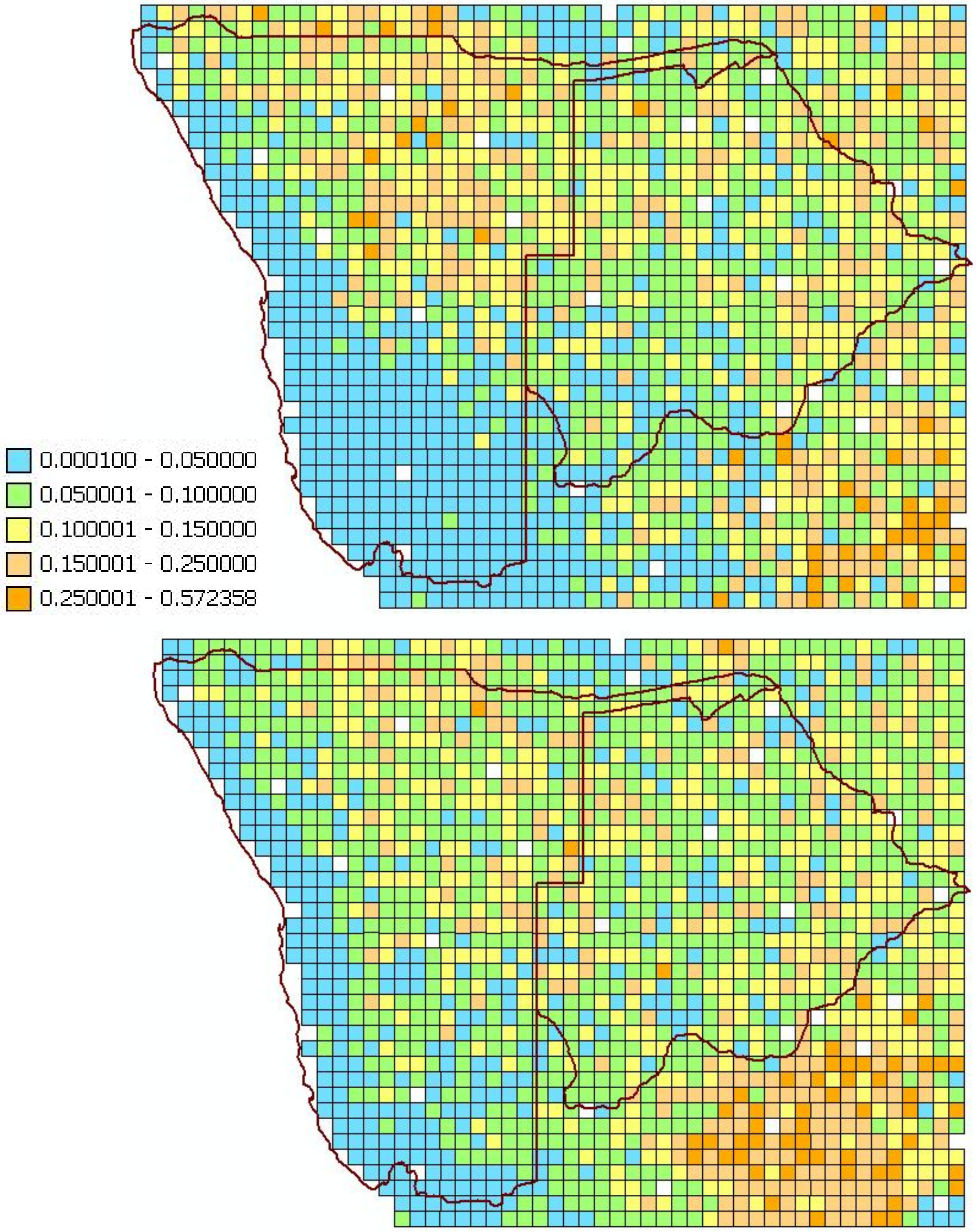


FIGURE 6.9. GRASS BIOMASS (KG PER M^2) IN 2009 (TOP PANEL) AND 2100 (LOWER PANEL)

6.7.4 Changes in plant species distributions

Midgley *et al.* (2005) modelled changes in plant species distributions under climate change. At the individual species range-level the predictions in terms of changes in overall range size were mixed – 52% of species modelled were expected to have range contractions, 41% to have range increases and 7% to be lost from Namibia (Figure 6.10).

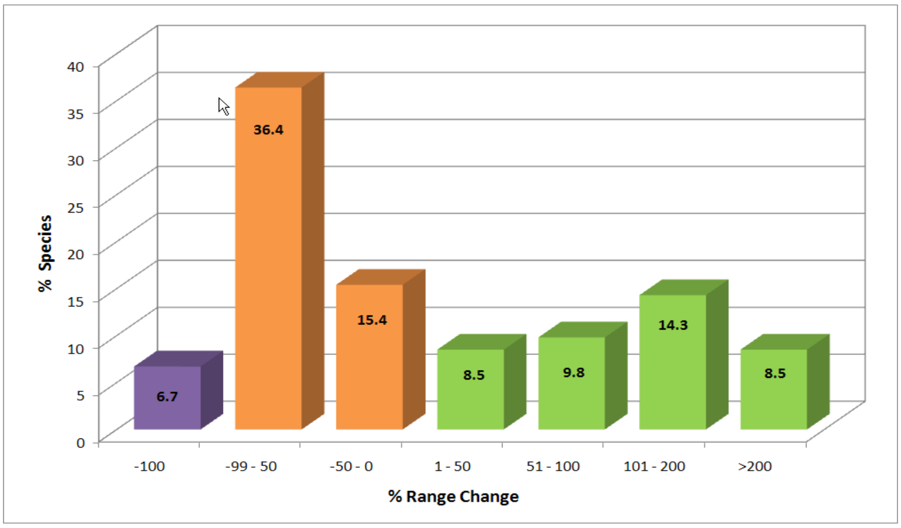


FIGURE 6.10. A SUMMARY OF THE PERCENTAGE CHANGE IN RANGE SIZE FOR THE 857 PLANTS SPECIES MODELLED BY MIDGLEY *ET AL.* (2005). -100% IMPLIES THAT A SPECIES HAS GONE EXTINCT FROM NAMIBIA

The areas expected to experience the greatest reduction in primary productivity (south and south west) are predicted to see the greatest increase in total species numbers as well as the lowest proportion of species loss. While this gain in species diversity in areas most affected by climate change is perhaps contrary to what might be expected, it may be related to the fact that Namibia is rich in species adapted to warm, dry conditions. With an expansion of such conditions and of low net primary productivity into the future, this rich group of arid-adapted species was expected to expand their range and migrate into regions that are warming and drying.

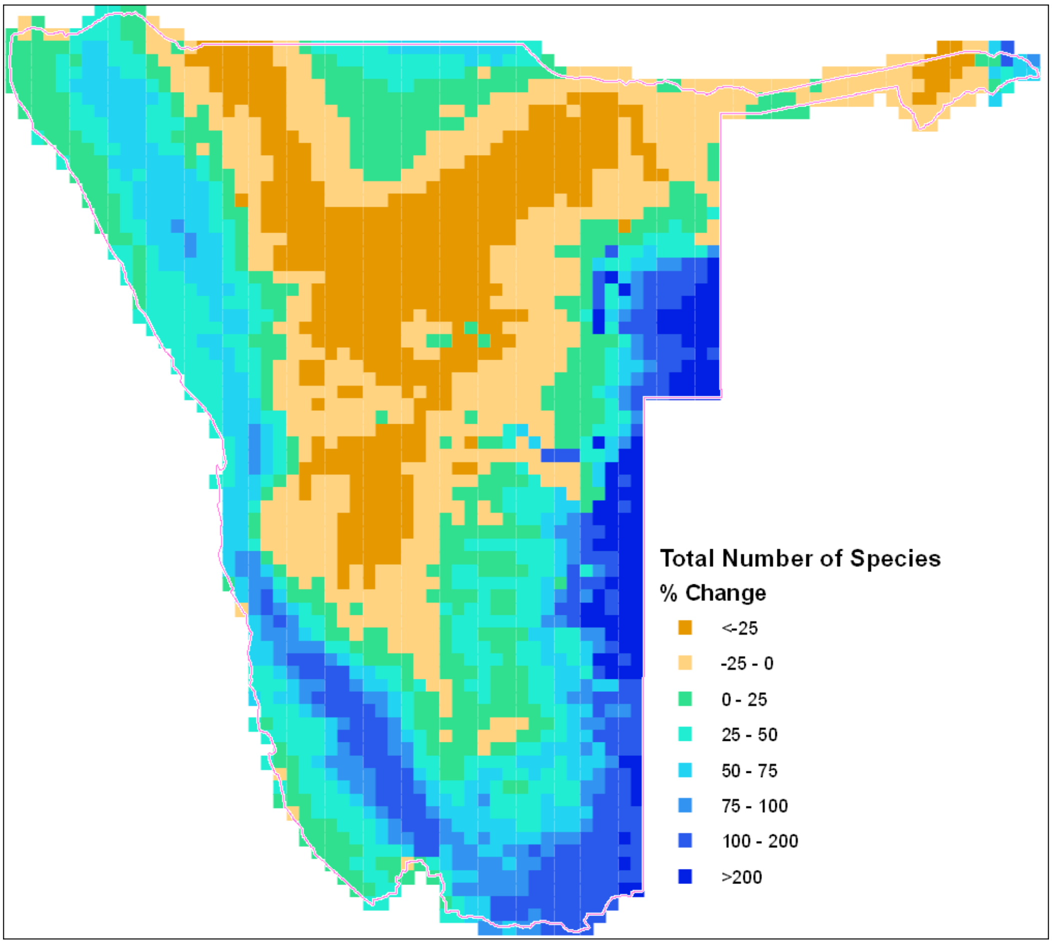


FIGURE 6.11. THE RELATIVE CHANGE IN TOTAL SPECIES NUMBERS ACROSS NAMIBIA 2000-2080 (ORIGINAL DATA FROM MIDELEY *ET AL.* 2005 AND BROENNIMANN *ET AL.* 2006)

6.7.5 Remobilisation of sand dunes

Vegetation in the sand seas of the Namib increases in abundance and diversity from west to east (Yeaton 1988). Close to the coast, there are only one or two species that inhabit the dunes (predominantly the grass *Stipagrostis sabulicola* and succulent shrub *Trianthema hereroensis*) both of which make direct use of fog precipitation. These plants inhabit the dune base and plinth and help to stabilize those parts of the dunes; on highly mobile upper parts of the dunes and slip-faces, living plants are absent. These plants can exist on fog but cannot germinate new plants in the absence of substantial (>20 mm) rain. Further inland, where fog incidence and precipitation are lower, and rainfall higher, there are more grass and shrub species on dunes, and greater coverage of the total dune surface by plants, with resultant less mobility of the dunes themselves. The mobility of the dunes is therefore chiefly determined by rain (though vegetation) and wind.

The shape of the central Namib sand sea is determined by winds, the erosive action of ephemeral rivers, and the topographic constraints of the Namib plain (Lancaster 1989, Seely 2004). The dunes have a predominantly north-moving trend pushed by the southerly and south-westerly winds on the west coast. Northward extension of the dune fields is stopped by the annual or semi-annual flows in the west-flowing ephemeral rivers, most conspicuously achieved by the Kuiseb River which separates the central Namib sand sea from the gravel plains to the north of it. Close to the coast these flows are less frequent and powerful, and sand is able to pass the river barrier and continue northwards. This explains the narrow dune field between Walvis Bay and Swakopmund. Decreased frequency and intensity of flows with climate change are likely to make these barriers less effective, so that dune field expansion along the Namibian coast can be expected.

On the eastern edge of the dune field, winds are less unimodal and there is a steady accumulation of sand, giving rise to star-shaped, very high dunes (e.g. around Sossusvlei). Significant eastward encroachment is prevented by the escarpment itself, so eastward expansion of the dune field beyond that barrier will not occur.

Eastward retreat of rainfall isohyets in future climate is predicted, which will likely make dune vegetation sparser. Uncertainty about fog makes it impossible to predict the dune-stabilising role of fog-dependent plants. With or without these plants, an increase in Namib dune mobility close to the coast can be expected.

In the Kalahari, remobilization of dunes is predicted (Thomas *et al*. 2005) under a wide array of climate predictions. The predicted decrease in vegetation cover and moisture availability will lead to increased sand mobility and will disrupt pastoral and agricultural systems, increasing the difficulties faced by rural people with crop- and livestock-based livelihoods. It is unknown whether remobilization will affect the size and shape of the expanse of Kalahari sand within the time horizon of this assessment.

6.8 Changes in distribution and abundance of key species

There are currently an estimated 5-10 million species of plants and animals on Earth. Of these, about 1.6 million species are known to science, perhaps fewer if synonyms were excluded. Many of these species remain poorly known. For example, for the largest taxonomic group, beetles, about 40% of species described are from a single site and many are known from a single specimen. Such meagre information provides little insight into their biology and ecological requirements.

The situation in Namibia is no different. Only some 14 000 species of plants and animals (including virusus, monerans, protists, fungi and lichens) are known, from a possible 100 000 species – perhaps 14%. The known species are highly skewed towards higher plants and vertebrates, with insects (estimated 5-20% described), arachnids (estimated 20% described), molluscs, lichens and fungi having received some limited attention.

Our limited knowledge on the biodiversity of many phyla, and the more limited knowledge on the ecological and biological characteristics and requirements of many described species means that any assessment on the impacts of climate change on Namibia's biodiversity must at best be an assessment of a small subset of species highly skewed to a few phyla that are reasonably well known and understood. However, even such a subset would be impossible to assess species by species. A biodiversity guild approach is therefore adopted, looking at the following groups of animals:

- Common savanna plains species
- Woodland species
- Flagship species
- Predators and scavengers
- Wetland species (ephemeral and perennial)
- Endemic species

There are four possible responses by species to climate change effects. They may:

- be climate tolerant, and show little change to changing climatic conditions;
- expand into new areas as they declines in parts of their existing areas;
- move to totally new areas; or
- be intolerant to climate change and unable to expand or move to and survive in new areas and therefore become extinct in the wild.

The management actions for each of the above biodiversity responses to climate change could be:

- do nothing – the species will look after themselves;
- reconfigure landscapes to facilitate expansion and survival in changing distributions;
- translocate species to new appropriate habitats and manage to ensure their survival; and
- apply ex-situ conservation.

The following considerations apply:

- Where climatic boundaries are close to habitat / ecosystem boundaries then species may be restricted at these boundaries and be unable to expand or change their range;
- Rainfall may not be the key factor determining the presence and relative abundance of a species. For example, some endemic bird species are more abundant in lower rainfall areas within their range, which may suggest that a

decline in rainfall in the higher rainfall areas within their range may have little impact on their abundance;

- In arid zones where biodiversity is adapted to large variability, mean rainfall may be less important than the high periodic peaks of rainfall or even extreme episodic events which may be the drivers of events such as recruitment; and
- The edges of populations and “fringe” subspecies / races are important from a genetic perspective, because this is where evolutionary processes are often most active and where species are best adapted to extremes. Conservation efforts have inclined to focus on the centres of species distributions. For climate change purposes arid fringe populations are important.

6.8.1 Common savanna (plains) species

The common savanna wildlife species of Africa make up the bulk of the plains game and generally occur in large herds. In Namibia these include: Burchell’s Zebra, Blue Wildebeest, Red Hartebeest, Springbok, Gemsbok, Buffalo and Eland, as well as Ostrich. These species are all adapted to semi-arid conditions, some to hyper-arid conditions such as Springbok, Gemsbok and Ostrich. Mobility is one of their main adaptations to aridity and highly variable climatic conditions, with migration and nomadism being key survival strategies. In the Namib Desert east-west movement patterns are particularly important in these species, for example after good rains Springbok and Gemsbok will move westwards and, as conditions get dryer, they move eastwards out of the Namib to the escarpment.

If systems were open and movement patterns were not constrained by fencing, then climate change would probably have limited impact on the distribution of those species adapted to hyper-arid conditions, as they would simply adjust their movement patterns in response to changing climatic conditions, perhaps visiting the extreme western areas less frequently. However, if fences were to be retained and secured, then movement would be blocked and high mortalities could be expected. This situation is already prevalent along parts of the Namib-Naukluft Park boundary and particularly for Gemsbok, but not where the Naukluft section provides access to the escarpment. Springbok and Gemsbok are thus unlikely to retreat from the most arid western and southern regions of Namibia. Their north-eastern range currently extends to about the 500-550 mm rainfall isohyets, which largely coincides with the transition from the savanna to woodland biome. Should the savanna biome shift in a north-easterly direction, as has been predicted by some models, then the ranges of both Springbok and Gemsbok would be expected to follow suit (Figure 6.12). This would see these species colonizing the BwaBwata National Park.

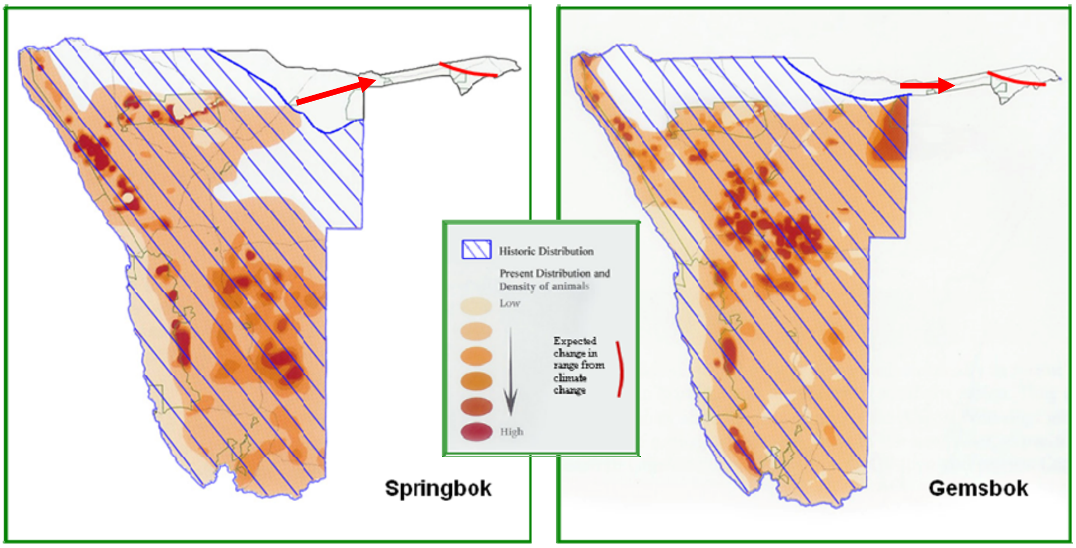


FIGURE 6.12. CURRENT AND HISTORIC DISTRIBUTIONS OF SPRINGBOK AND GEMSBOK IN NAMIBIA, BOTH ADAPTED TO HYPER-ARID CONDITIONS, AND THE POSSIBLE EXPANSION OF THEIR RANGES TOWARDS THE NORTH-EAST BY ABOUT 2050 AS THEY FOLLOW THE RETREATING 500 – 550 MM RAINFALL ISOHYETS, AND PROVIDED THE SAVANNA BIOME FOLLOWED SUIT

The other savanna plains game species not adapted to hyper-arid conditions are seldom found in the driest western regions of Namibia below about 100 mm of mean annual rainfall. An increase in aridity is expected to shift the 100 mm rainfall isohyets east and north, and the ranges of species such as Burchell's Zebra, Blue Wildebeest and Red Hartebeest are expected to follow suit (Figure 6.13).

In terms of relative abundance based on predicted range and carrying capacity changes resulting from projected climate change impacts (see wildlife section in 3.1.4.4), and with all else being equal, wildlife grazers are expected to decline on average by about 13% by 2050 and about 24% by 2080. However, other factors are unlikely to remain equal. First, there are large areas within the historic ranges of the different species where they do not currently occur. There is an ongoing expansion of range and increase in numbers of most wildlife species across Namibia, and it is reasonable to expect this to continue and accelerate under the impacts of climate change. So, while local carrying capacity may decrease, the ranges of plains game will probably increase. Second, we predict that there will be an ongoing shift from livestock to wildlife production systems across much of Namibia. Grazing currently used by domestic stock in these areas will become available to wildlife. Third, in response to the shift towards wildlife production systems, wildlife-based industries will probably become more efficient, particularly the venison sector, both via its domestic and export markets, thereby creating further economic incentives for wildlife production. Fourthly, we predict that the importance of creating incentives for open, co-managed landscapes through policy and legislative reform will start to be accepted and implemented by the Ministry of Environment and

Tourism, that the national parks will begin to implement park-neighbour co-management actions as set out in their park management and development plans and that the state protected area network, freehold land under wildlife and tourism management, communal conservancies and the private sector will begin to effectively collaborate around the management and marketing of large landscapes. This will lead to the establishment of large open systems which will allow for wildlife mobility, support a relatively greater biomass of wildlife than do small closed systems, and enhances ecosystem resilience. For these reasons it is expected that wildlife numbers will actually increase significantly across Namibia in the years ahead.

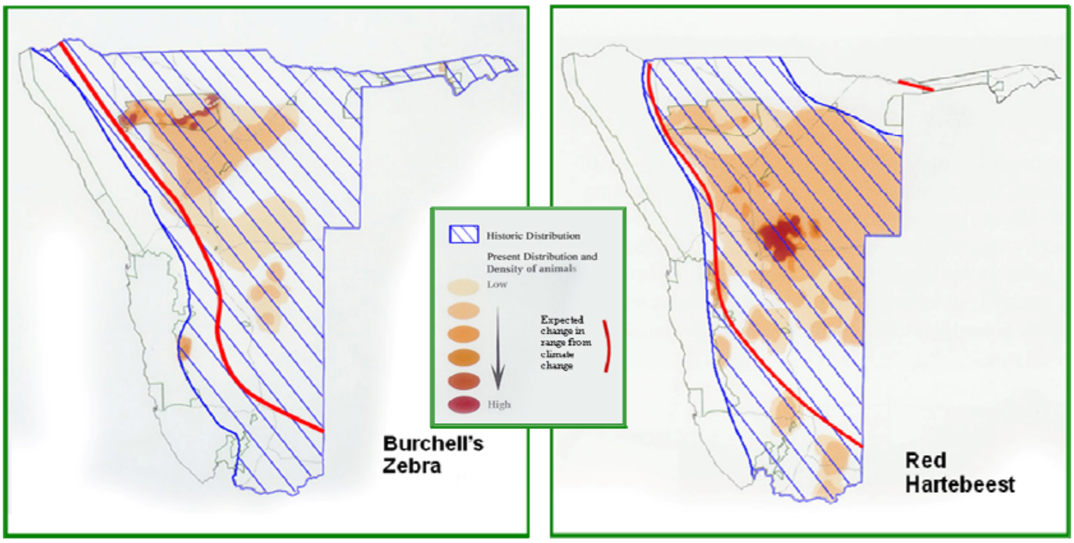


FIGURE 6.13. CURRENT AND HISTORIC DISTRIBUTIONS OF BURCHELL'S ZEBRA AND RED HARTEBEEST IN NAMIBIA, BOTH SAVANNA SPECIES NOT ADAPTED TO HYPER-ARID CONDITIONS, AND THE POSSIBLE CHANGE IN THEIR RANGES AWAY FROM THE EXTREME WEST AND SOUTH BY ABOUT 2050 AS THEY FOLLOW THE RETREATING 100-150 MM RAINFALL ISOHYETS

In summary, the plains game of Namibia can be classed as largely climate tolerant, with small expansions of range in some species towards the north-east in response to an expected shift of the savanna biome, and small declines in the ranges of some species in the extreme west and south as the hyper arid Namib expands. In terms of protected area, it is expected that Springbok and Gemsbok will expand their ranges to the BwaBwata National Park but that none of the ranges of plains game species will retreat out of any of the national parks. If parks are managed as isolated units and fenced, then the numbers of plains game will decline because the overall carrying capacity will decline. This will be particularly severe in the most arid regions, e.g. Namib-Naukluft Park and Sperrgebiet National Park, where wildlife numbers may crash to very low levels. This situation can be mitigated by implementing park-neighbour initiatives to create co-managed open landscapes.

Before moving off the common plains game it is necessary to comment on the situation of the Buffalo. Historically this species roamed over the whole of Namibia except for the extreme western Namib, with a similar distribution to that of Burchell's Zebra. Today the species is confined to the eastern Kavango and Caprivi regions, with two small isolated populations of disease-free animals in the Waterberg Plateau Park and in a fenced game camp in the Nyae-Nyae conservancy. The present range of the Buffalo in Namibia is a direct result of veterinary legislations that prohibit its presence elsewhere. It is amongst the most valuable of wildlife species (disease-free buffalo sell for about N$250 000 per animal at Namibia game auctions – but they may not be sold for introduction within Namibia) and would substantially increase the revenue to wildlife producers, by an estimated 35%.

The wildlife sector is being severely constrained by cattle farming interests. This is ironic, as the wildlife and tourism sector outperforms the livestock sector by a handsome margin in terms of contribution to the national economy, creates more jobs per hectare and is expanding at the expense of the livestock sector. Wildlife based production systems offer a very attractive alternative to livestock production under deteriorating climatic conditions and, if fully unleashed from policy constraints such as those imposed on Buffalo, would not only make up for lost livestock revenue, but would significantly improve on the current situation for both revenue and job creation. It is critical that Buffalo as a wildlife production species be subject to an independent economic assessment to show its huge value to the local and national economy and to reform current policy so that these values may be realized.

6.8.2 Woodland species

Namibia's woodland ungulates include Tsessebe, Roan and Sable Antelopes. They have their natural range mainly in the north-east of the country in the woodlands biome, where mean annual rainfall exceeds 400 mm. They presently occur also outside their natural ranges on freehold farms because of their high value at live sales and for trophy hunting. Namibia is the only country in southern Africa attempting to maintain populations of Roan, Sable and Tsessebe where the annual average rainfall is below 400 mm and in dry periods will require supplementary feeding. These species are all highly water dependent and are seldom found more than a few km from a reliable source of water. They are selective grazers and are sensitive to habitat changes. Many of the observed "crashes" in the populations of these species occurred in areas near to the 400 mm rainfall isohyet, and it may be concluded that populations at 400-600 mm are highly vulnerable to climatic variability, specifically prolonged dry phases and a lack of early rains at the end of the dry season.

It is clear that the woodland species are less tolerant to both climatic variation and long-term climate change than the plains ungulates. It is expected that their ranges will retreat towards the north-east (Figure 6.14) and that the populations will fluctuate in response to wet and dry phases. Managers should be prepared for population "crashes" under dry conditions and late rains.

These woodland ungulates are not dominant species, typically occurring at densities of one or two animals per 100 ha. Because of their sensitivity to climatic variation on the edge of their natural distribution – essentially their range in Namibia falls within this "edge" effect - it is difficult to predict what changes might be expected in their more restricted range as a result of declining carrying capacity. However, they are currently at well below carrying capacity in the parks with the most favourable conditions, namely the Khaudum, BwaBwata and Mudumu National Parks. The reasons for this are probably due to factors other than rainfall such as elephant impacts on habitat, water supply, fires and illegal hunting. With careful management and, in particular, maintaining open systems with neighbouring wildlife areas in Namibia (e.g. conservancies and forestry areas) and with those in neighbouring countries, particularly Botswana, it is possible to significantly rebuild the populations of these three high value woodland species in the eastern Kavango and Caprivi despite the expected effects of climate change.

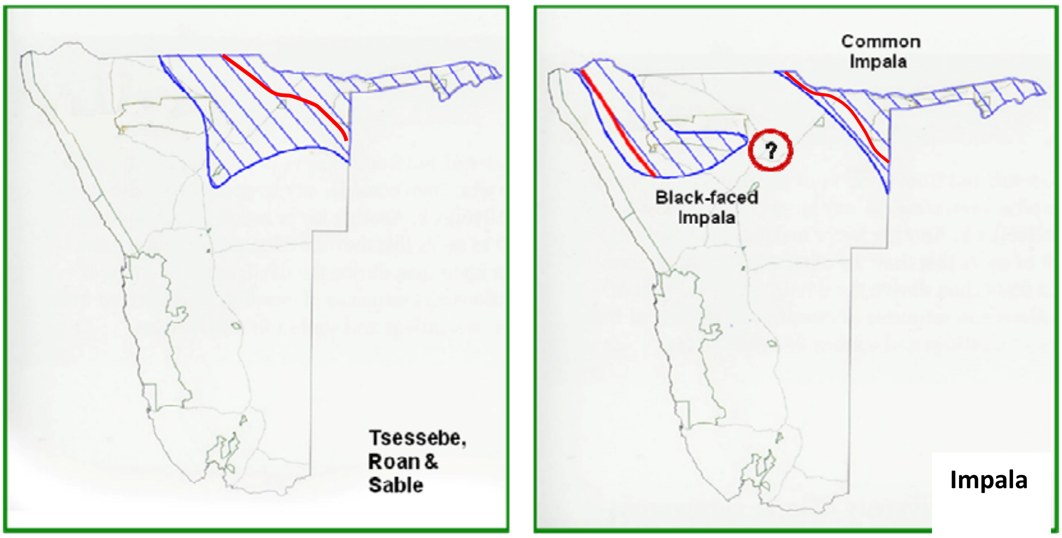


FIGURE 6.14. HISTORIC DISTRIBUTIONS OF TSESSEBE, ROAN AND SABLE ANTELOPE AND COMMON IMPALA IN NAMIBIA, ALL WOODLAND SPECIES, AND THE POSSIBLE CONTRACTION IN THEIR RANGES TOWARDS THE NORTH-EAST BY ABOUT 2050 AS THEY FOLLOW THE RETREATING 450 MM RAINFALL ISOHYET

In summary, the woodland ungulates are more sensitive to climate change and climatic variability than the plains species. This is exacerbated by the natural distribution of these species in Namibia being on the drier edges of their ranges where they are particularly vulnerable. A retreat in natural ranges to the north-east should be expected. In terms of protected areas, populations of these species in the Etosha and Waterberg Parks are not expected to prosper under a projected climate change scenario, and the Ministry of Environment and Tourism should focus its conservation efforts for these species on the Khaudum, BwaBwata and Mudumu Parks. Open systems should be maintained with neighbouring areas which are under compatible forms of land use, both within Namibia and across international borders, particularly with Botswana. Where populations of these species are held below about 400 mm mean annual rainfall, supplementary feeding will be required in dry times. Because of their high value, this may be a viable economic option for wildlife production systems.

Another consideration is the two subspecies of impala that occur in Namibia: the Common Impala in the north-east and the Black-faced Impala in the north-west. They are woodland species, the latter favouring dry riverine and valley bottom woodlands. They both browse and graze, and are water dependent. Impala are important production animals as they reproduce rapidly, provide excellent meat and are attractive for tourism and trophy hunting. They are also fairly resilient to climate variability because of their broad diet. Black-faced Impala are more valuable than Common Impala because they are endemic to a small area in north-west Namibia and south-west Angola and are in limited supply. Their ranges are not expected to change significantly as a result of climate change, perhaps retreating slightly to the east. An opportunity may also exist for expanding the range of the Black-faced Impala into the Otavi Mountains. It is important that all Common Impala are removed from the area prior to reintroductions to avoid hybridization. As both subspecies of Impala are below carrying capacity throughout their ranges, climate change impacts will not constrain present populations which should be able to expand considerably, both to occupy unpopulated areas within their ranges and to increase in numbers.

6.8.3 Flagship species

These are species chosen to represent an environmental issue or ecosystem. They are chosen because of their vulnerability and distinctiveness to show pressures and engender support for broader conservation action. These iconic species represent some of Namibia's best know wildlife, such as the Elephant, Rhinos, Giraffe and Hartmann's Mountain Zebra. Other flagship species such as predators, cranes and vultures will be dealt with under specific guilds (predators and scavengers, wetland species).

Elephants are able to survive in a wide range of habitats, even extending along dry river courses into the extreme Namib Desert. Their historic range in Namibia covered virtually the entire country (Figure 6.15). Unlike most species that respond to habitat conditions, Elephants are able to significantly modify and damage their habitat. At population densities approaching one Elephant per 200 ha, up to 50% of the canopy trees are likely to be destroyed. The idea that Elephants may reach some stable equilibrium with their habitat while it still retains its productive state has been shown to be a myth. A number of studies have clearly demonstrated that biodiversity is reduced by the action of Elephants. Elephant numbers in some areas (e.g. parts of eastern Kavango and Caprivi) probably already exceed desirable levels. Elephant numbers will not decline with lower carrying capacity. Rather, they will continue to increase until environmental conditions get so dire that the population crashes. Declining rainfall and carrying capacity will lead to Elephants exerting extra pressure on habitats, and speed up habitat modification and damage to the disadvantage of other species and the biodiversity richness of the area. It is therefore important that active Elephant management is implemented as part of a climate change response, to prevent habitat damage and biodiversity loss.

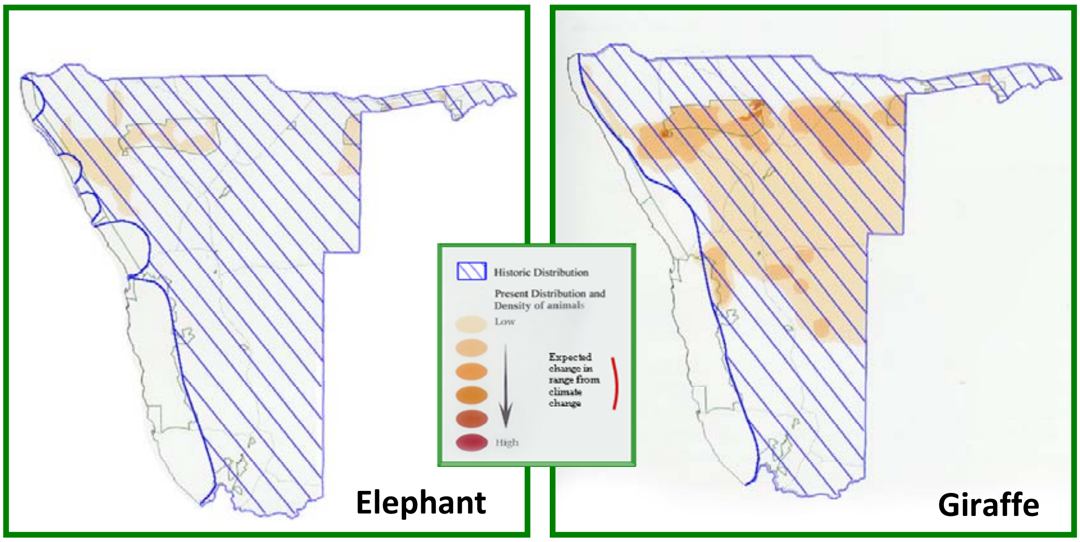


FIGURE 6.15. CURRENT AND HISTORIC DISTRIBUTIONS OF ELEPHANT AND GIRAFFE IN NAMIBIA. THEIR RANGES ARE UNLIKELY TO CHANGE SIGNIFICANTLY

It is apparent from the current and historic distribution of Elephants in Namibia that the species occupies a very small part of its former range. Large areas are not currently suitable because of high human density and conflicting land uses. However, as more land is placed under wildlife management and as co-managed landscape approaches are adopted over large areas, so will Elephant range and numbers increase, because they make an economically significant contribution to wildlife production systems, through tourism (about N$30/ha), trophy hunting (N$8/ha) and cropping (about N$15/ha).

Giraffe also survive in a wide range of habitats across Namibia and into the edge of the Namib Desert in areas that receive less than 100 mm of rainfall (Figure 6.15). Like Elephants, they make use of ephemeral rivers and drainage lines supporting trees and shrubs, and are capable of moving large distances in response to rainfall. Their range is not expected to change significantly, though carrying capacity may decline in the extreme southern and western areas where populations may become a little patchy. However, for the reasons already stated on the expected expansion of the wildlife sector, their distribution and numbers are expected to increase within their historic range.

The historic distributions of Black and White Rhinoceros in Namibia are shown below (Figure 6.16). Being a browser, the Black Rhino is able to tolerate more arid conditions than the White Rhino which is a grazer. The range of the Black Rhino is not expected to change, though a decline in carrying capacity may result in areas of high population, such as in Etosha National Park and parts of the Kunene Region, being overpopulated. Animals should be removed from these high density areas and used to start new populations in areas that have the potential to support significant meta-populations, e.g. in Khaudum and Ai-Ais National Parks, Nyae-Nyae and N≠a_Jaqna conservancies.

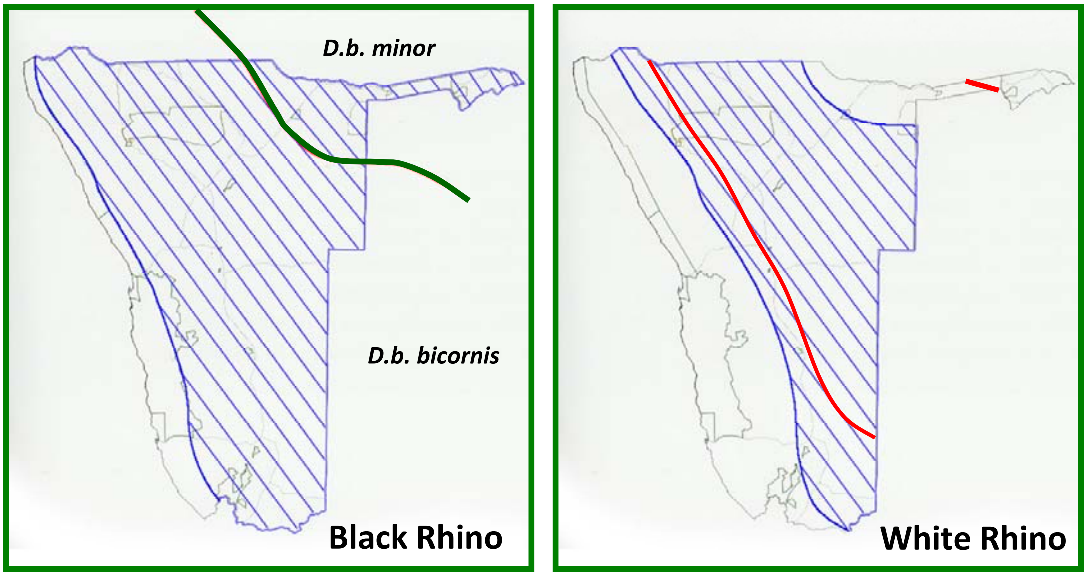


FIGURE 6.16. HISTORIC DISTRIBUTIONS OF BLACK AND WHITE RHINOCEROS IN NAMIBIA. THE GREEN LINE IN THE RANGE OF THE BLACK RHINO SHOWS THE APPROXIMATE DEMARCATION OF THE TWO SUBSPECIES THAT OCCUR IN SOUTHERN AFRICA, *DICEROS BICORNIS BICORNIS* OCCUPYING THE ARID WESTERN AREAS, AND *D. B. MINOR* TO THE EAST. THE RANGE OF THE BLACK RHINO IS NAMIBIA IS NOT EXPECTED TO SHIFT AS A RESULT OF CLIMATE CHANGE. THE WHITE RHINO, BEING A GRAZER, IS MORE VULNERABLE TO CLIMATE CHANGE, AND ITS RANGE IS PREDICTED TO RETREAT FROM THE WEST AND EXTREME SOUTH AND POSSIBLY EXPAND TOWARDS THE NORTH-EAST

By contrast, the range of the White Rhino in Namibia is expected to retreat from the west and south and to expand to the north-east, possible making the Khaudum and BwaBwata National Parks suitable habitat by 2050. The prediction that grasslands will prosper at the expense of woodlands in north-eastern Namibia would further favour White Rhinos. The establishment of new White Rhino populations west of Windhoek and south of Mariental should be discouraged.

Hartmann's Mountain Zebra is a near endemic subspecies that just enters south-western Angola. It occupies the western escarpment belt and the central highlands (Figure 6.17), extending deep into the Namib after good rains. It is a highly nomadic species and shows clear west-east movements patterns. Being adapted to the semi-arid and arid regions of Namibia, it is tolerant to conditions of low rainfall and climatic variability. Its range is not expected to change significantly as a result of climate change, though populations may adjust to declining carrying capacity. It is important that park-neighbour and co-managed landscape approached are implemented to allow this species to move over large areas. If this is achieved, its populations will be secure and continue to increase, despite the impacts of climate change. It is also worth exploring the introduction of this species to the Otavi mountain range as conditions there get drier.

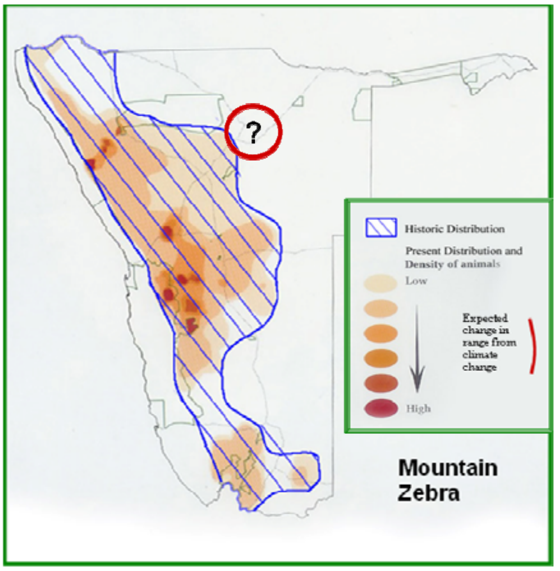


FIGURE 6.17. PRESENT AND HISTORIC DISTRIBUTIONS OF HARTMANN'S MOUNTAIN ZEBRA IN NAMIBIA

6.8.4 Predators and scavengers

These two groups are treated together because many species are opportunistically both predator and scavenger, and because the distributions and numbers of both groups are usually set by the numbers of herbivores rather than by rainfall or habitat per se. The historic distributions of most predators covered the entire country. Some species were probably infrequent visitors to the extreme arid Namib such as Lion and African Wild Dog, but when ungulate numbers were large in these areas in response to rainfall, the predators would have followed them. Their present range is mainly influenced by direct persecution by farmers in response to predation on their livestock. The tolerance of predators to arid areas is clearly demonstrated by the recent expansion of the Lion population in the Kunene Region into areas of less than 100 mm mean annual rainfall, the increase in leopard numbers in the Fish River Canyon area at less than 100 mm and the increase in Cheetah numbers along the edge of the Namib in the Sossusvlei area at about 70 mm – all areas where wildlife numbers have increased significantly as a result of wildlife and tourism based industries being established.

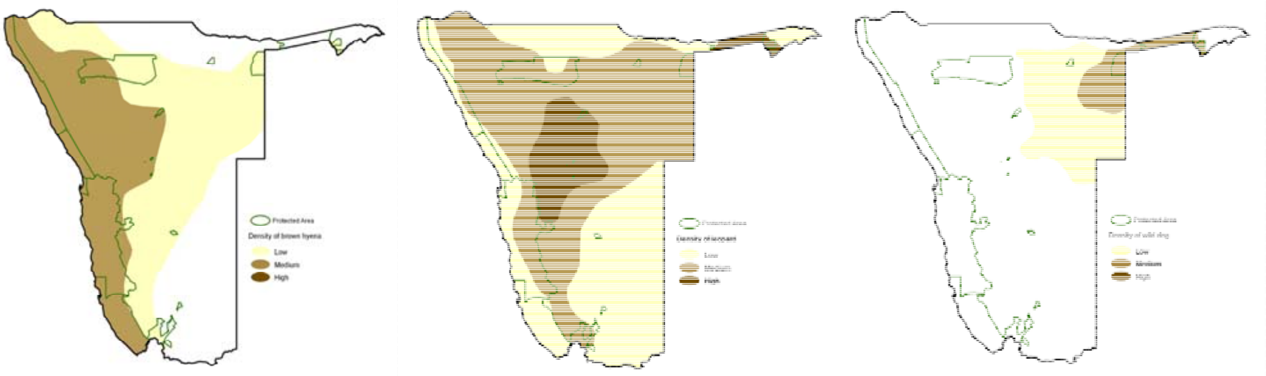


Figure 6.18. Present distributions of Brown Hyaena, Leopard and African Wild Dog in Namibia

The range and abundance of scavenging species in Namibia have also been severely impacted by farming practices, particularly the indiscriminate use of poisoned bait to kill predators but which are more efficiently found by scavengers, particularly birds. Small-stock farming areas are particularly impacted, and avian scavengers were estimated to be at less than 20% of their potential numbers based on the available food supply. In the central mixed cattle and small-stock area, their abundance was at about 50% while in the mainly cattle farming areas where less poison in used avian scavengers were found to be at about 70% of their carrying capacity. These impacts are illustrated by the distribution patterns of two vulture species, the White-backed Vulture which occurs mainly in the savanna and woodland biomes, and the Lappet-faced Vulture which favours more arid and hyper-arid desert systems (Figure 6.19). Climate change is not expected to have any significant direct effect on the distributions of these scavenging species. However, some indirect effects may be expected. If farmers turn more to small-stock farming in areas which become less suited to cattle farming, an increase in the use of poisons may be expected which will have a negative impact on scavengers, particularly vultures and scavenging eagles which are very vulnerable. If farmers turn more to wildlife and tourism, then this will have a positive impact on scavengers. In practice, both these responses are likely. Because of the large foraging ranges of scavenging birds, it has been found that just one of two farmers using poisons indiscriminately in 100 000 ha and more will cause the decline of avian scavengers. The disproportionately large negative impact of a few farmers using poisons runs the risk of undermine the positive impacts that would result from more land under wildlife and tourism.

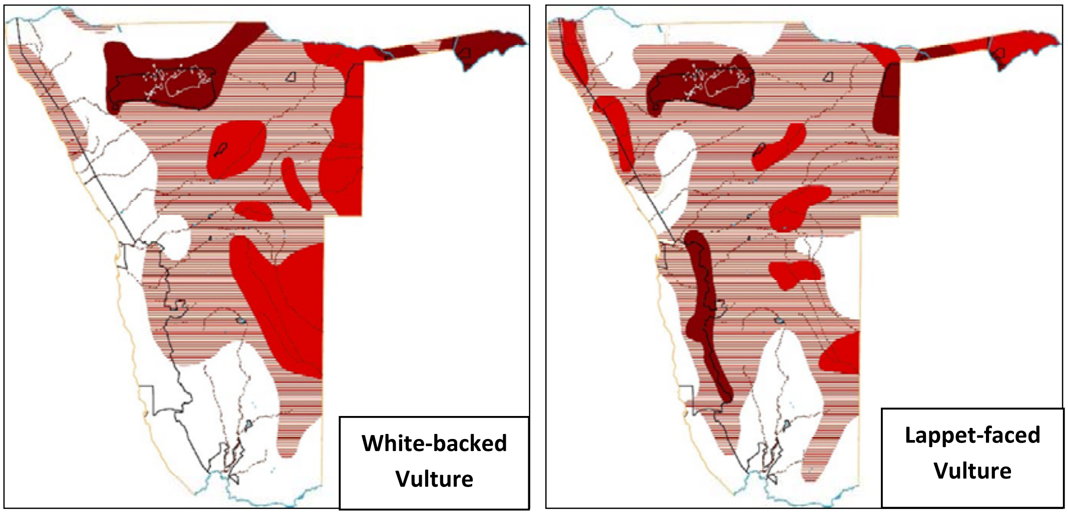


FIGURE 6.19. DISTRIBUTIONS OF WHITE-BACKED VULTURE AND LAPPET-FACED VULTURE IN NAMIBIA. THE FIRST FAVOURS MAINLY THE SAVANNA AND WOODLAND BIOMES, THE SECOND MAINLY THE ARID AND HYPER-ARID DESERT SYSTEMS

Woody plant biomass is projected to decrease over much of Namibia, particularly in the density of woody plants less than 2 m (small trees and shrubs). This suggests that bush-encroached areas are likely to open up. The deteriorating status of the Cape Vulture in the Waterberg area has been linked to bush encroachment as one of the key factors. Any significant reduction in woody biomass is likely to be advantageous for the Cape Vulture.

In conclusion, predators and scavengers are largely climate tolerant. If their food source is secure their distribution and abundance will be little affected. Protected areas and land under wildlife and tourism are vital for their long-term survival because predators are heavily persecuted in livestock production areas and scavengers are killed by poisons targeted at predators. A shift towards small-stock will increase the risk to predators and particularly scavengers, and the issue of poison use for predator control needs urgent attention. An ongoing shift towards wildlife-based land uses, particularly those primarily for tourism, and the establishment of large open co-managed systems will lead to the recovery of predators and scavengers, both groups being important for tourism and even more so for providing ecosystem services.

6.8.5 Wetland species

Wetlands are pressure points in arid and semi-arid systems. They provide vital ecosystem services, are rich in biodiversity and are often fragile and vulnerable to overuse and abuse. They are also vital to the survival of many non-wetland species. The well-being of wetland species is usually directly linked to the status of wetlands. The impacts of climate change on wetland systems are difficult to predict as insufficient work has been done to derive any clear projections. Some likely scenarios are applied to look at possible impacts on some selected species.

Namibia's main permanent wetlands comprise the river systems on its northern and southern borders, as well as some permanent sink-hole lakes, springs and man-made dams. The northern river systems are largely unregulated (there is some limited regulation on the Kunene), while the Orange River is so heavily regulated that flows received in the lower Orange system are totally unrelated to natural run-off and result from the management of dams in South Africa. Future flows in this system are likely to be determined primarily by the socio-economic needs of South Africa, and it would be prudent to plan on reduced flows in future as pressures of water shortage increase in South Africa.

The northern rivers have the heads of their catchments between about 500 and 800 km north of Namibia. These areas are predicted to experience an increase in rainfall of up to about 10% as a result of climate change. It is therefore reasonable to expect that water volumes in these river systems will increase and that flooding may be more frequent and of greater magnitude. While this will have initial negative consequences for people it will have positive ecological impacts. It will favour resident wetland and floodplain species such as Hippopotamus, Sitatunga, Lechwe, Reedbuck, Puku, otters, Crocodile, wetland birds such as Fish Eagle, Wattled Crane, ducks, storks and many others, as well as fish, molluscs and other invertebrates. It will also favour migratory and nomadic wetland species such as some ducks, waders and African Skimmer. It will have positive impacts on fish recruitment and production, for both subsistence and tourism. It offers the potential to expand tourism and wildlife-based enterprises as people are forced to move off the floodplains.

Namibia's ephemeral wetland systems are also vitally important to people and biodiversity. They comprise river systems which flow for short periods, and temporary pans and springs. With the exception of the Cuvelai system which rises some 200 km north of Namibia in the Angola highland and ends in the Etosha National Park, all ephemeral wetlands have their catchments in Namibia. This means that they will be subject to decreasing rainfall and increasing temperatures and rates of evaporation which will probably result in less frequent flooding, of lower magnitude (less water) and of shorter duration. This will have a negative effect on recharge of aquifers, a lowering of the water table and less surface water available. Similar effects may occur in some of the currently perennial wetlands such as sink-hole lakes, springs and dams, which may have reduced yields, become ephemeral and, in the case of some springs and artesian wells not produce enough water to reach the surface. The implications for biodiversity could be severe. Lowering of water tables through water abstraction has resulted in the death of large tree species such as *Faidherbia albida* in ephemeral rivers. These trees provide essential fodder and habitat to many other species and any significant mortality to riparian belts in these ephemeral systems would have significant biodiversity implications.

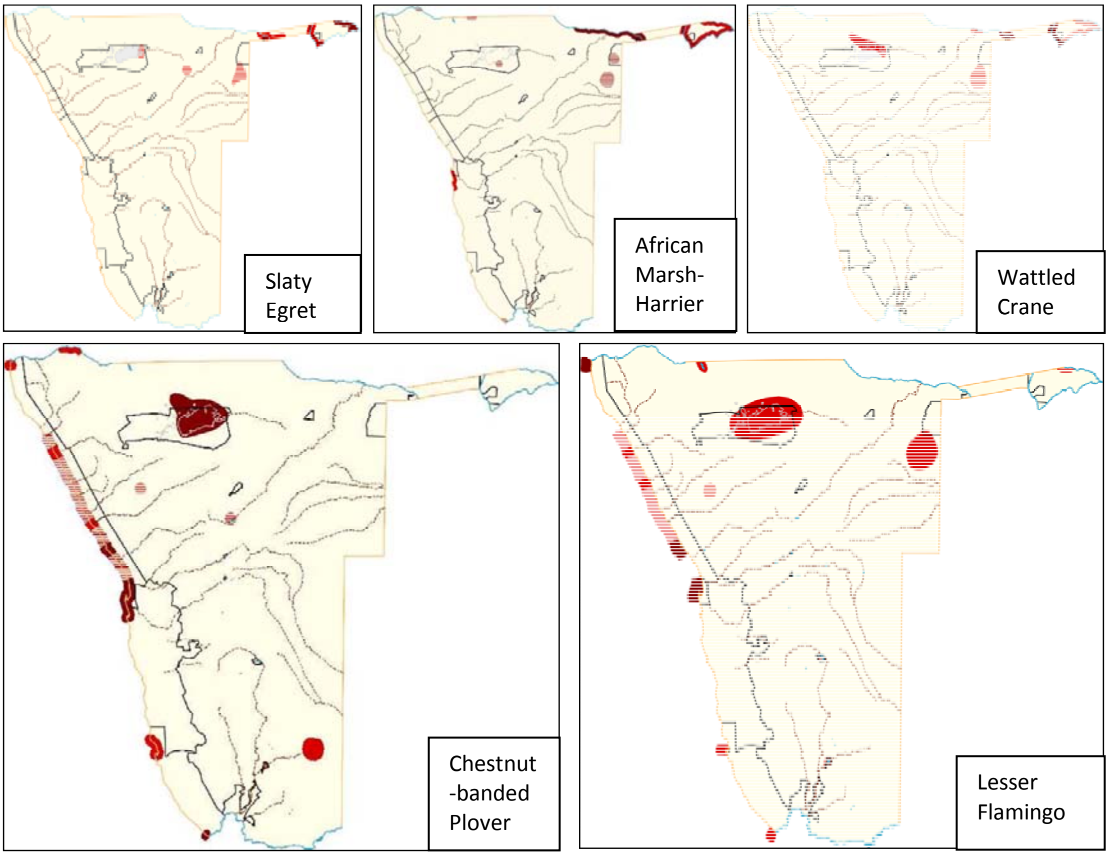


Figure 6.20. Five Red Data wetland species. The top three favour floodplains and marshes. They are likely to prosper on the floodplains of the northern perennial rives but experience deteriorating conditions on the inland ephemeral wetlands. The lower two species favour flooded salt pans for breeding and saline coastal flats and wetlands when not breeding – mainly the Ramsar sites of Walvis Bay and Sandwich Harbour where up to 96% of the nominate subspecies of the Chestnut-banded Plover occurs. Up to 100,000 Greater Flamingos and 1.1 million Lesser Flamingos may gather in the Etosha Pan to breed, on average once every 7-10 years. Climate change impacts on the frequency, extent and duration of flooding of Etosha Pan could have serious negative implications on the status of Flamingos and the Chestnut-banded Plover

There are five Ramsar wetlands in Namibia, only one inland, namely the Etosha Pan. The catchment of the Cuvelai system feeding the Etosha Pan is probably not far north enough in Angola to benefit from increased rainfall from Climate Change. This system floods when above average rainfall occurs in both the Angolan and Namibia sections of the catchment. It is likely that most or all of the catchment will receive less rainfall resulting in less water entering the system. This deltoic wetland supports not only some 35% of the people of Namibia but provides Namibia's most important tourism attraction with water – the Etosha National Park. At present this system experiences a major flood every 7-10 years. Climate change may lead to less frequent floods of shorter duration, which may impact on the ground water of the park, the natural springs around the southern parts of the pan and on the breeding a recruitment of Greater and Lesser Flamingos for whom the Etosha Pan provides essential breeding conditions when flooded. The only other breeding area in southern Africa is the Makgadikgadi Pan in Botswana, which will probably experience similar drying conditions to those in Namibia.

In light of the pressures on wetlands in Namibia it is important that a national wetlands policy and action plan be agreed and implemented that takes full account of the catchments of the wetlands, the potential impacts of climate change and that looks at safeguarding these essential ecosystems. This process should also assess the Eastern Zambezi-Chobe River and floodplains, the Kwandu-Linyanti system, the lower Kavango River in Namibia and the Nyae-Nyae Pan system in the Tsumkwe District as potential Ramsar sites.

In conclusion, the wetland species associated with the large river systems in the north of Namibia are expected to prosper, while the conditions for wetland species at other wetlands in Namibia, both perennial and ephemeral, are likely to deteriorate. Of particular concern is the situation of the Cuvelai and Etosha Pan which is essential to the survival of flamingos in southern Africa (Figure 6.20).

6.8.6 Endemic species

Namibia's endemic plants and animals occur mainly along the western escarpment in a belt running from the Orange to the Kunene Rivers, and extending westwards into the Namib Desert and Succulent Karoo and east across the central highlands (Figure 6.21). The belt of greatest endemic diversity occurs east of the coastal national parks and west of Etosha National Park; and south of eastern Etosha via Windhoek to the Naukluft Mountains and into the Sperrgebiet. This belt does not extend significantly into the national parks network, but occurs on communal lands mainly in the Kunene and Erongo regions, and on freehold land in mainly the Otjozondjupa, Khomas and Erongo regions. Much of this land falls within communal and freehold conservancies.

The endemic belt extends mainly from about 50 to 350 mm mean annual rainfall through a particularly steep rainfall gradient in the north-west over a distance of just 200 km.

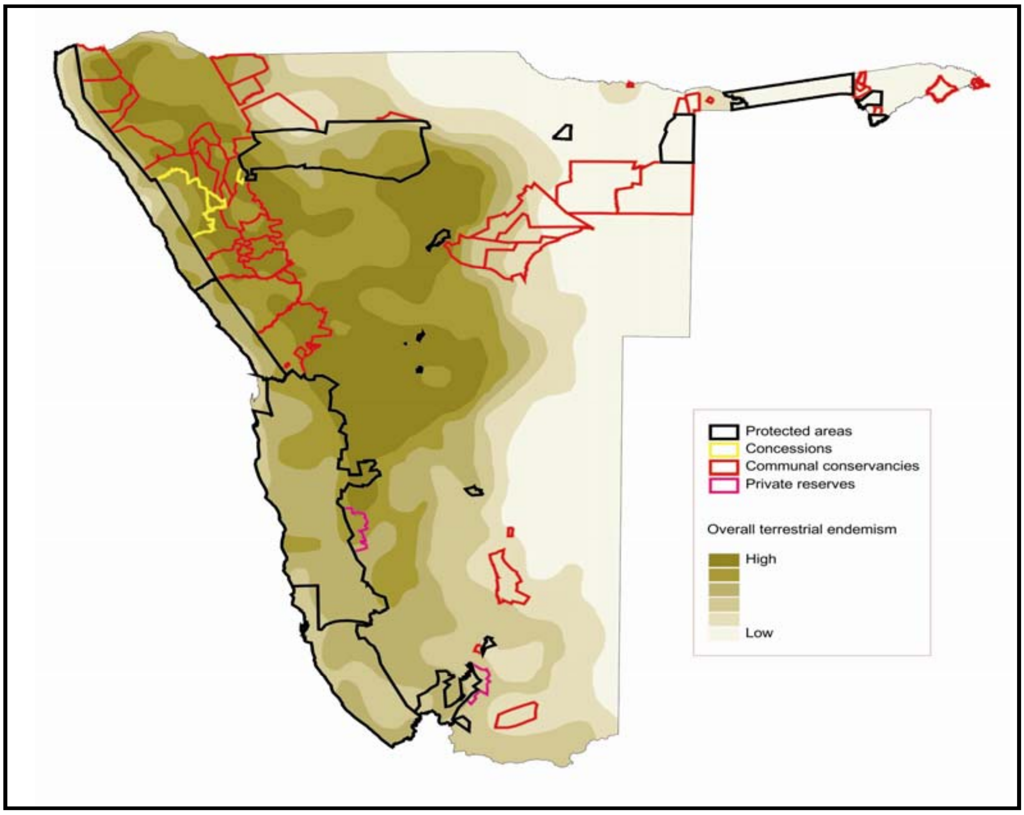


FIGURE 6.21. THE DISTRIBUTION OF TERRESTRIAL ENDEMIC DIVERSITY IN NAMIBIA

The most comprehensive work on endemic species related to rainfall has been done on birds. Of nine species studied the densities of six were found to be correlated primarily with vegetation and, secondarily, four with altitude and two with rainfall; the densities of two species were correlated primarily with rainfall and secondarily with altitude; and one species was correlated with altitude (Table 6.1).

If the density of most endemic bird species is not explain primarily be rainfall, then a decline in rainfall may not directly influence their range or abundance. The western limit of the range of the escarpment species is determined by habitat transition to the Namib plains (Figure 6.22). This suggests that these endemic escarpment species could live at lower rainfall than is currently the case if their habitat extended further west or, conversely, if the rainfall in their current distribution were to decline. Their eastern limit seems to be set, at least in two species, by rainfall, the Herero Chat on about the 300 mm isohyets and the White-tailed Shrike on about 430 mm. Should these rainfall isohyets shift to the east as a result of Climate Change, then the ranges of these species would be expected to follow suit within suitable habitat. In terms of ecosystem structure, the dynamic global vegetation model referred to elsewhere in this report suggests that, by 2100 the density of woody plants less than 2 m tall will decline along the western escarpment and central highlands and that the density of woody plants greater than 2 m tall will increase in the extreme northern escarpment area of Kunene.

Table 6.1. Variables accounting for densities of endemic bird species and numbers

Species	Variables (primary & secondary) influencing density outside river systems	Approximate numbers of birds within different classes of land tenure			
		Freehold	Communal	National Parks	National Totals
Hartlaub's Francolin	Vegetation, altitude	20 000	4 000	2 000	26 000
Rüppell's Korhaan	Vegetation, rainfall	30 000	47 000	23 000	100 000
Rüppell's Parrot	Vegetation, altitude	19 000	7 000	3 000	29 000
Violet Wood-Hoopoe	-	1 000	1 000	?	2 000+
Monteiro's Hornbill	Rainfall, altitude	242 000	81 000	16 000	339 000
Carp's Black Tit	Rainfall, altitude	329 000	141 000	24 000	494 000
Bare-cheeked Babbler	Vegetation, altitude	40 000	6 000	32 000	78 000
Herero Chat	Altitude	40 000	65 000	2 000	107 000
Rockrunner	Vegetation, altitude	61 000	28 000	8 000	97 000
White-tailed Shrike	Vegetation, rainfall	982 000	490 000	28 000	1 500 000

The converse situation applies for Namib plains species such as Rüppell's Korhaan whose eastern limit is set by the transition to the escarpment. Small numbers of Rüppell's Korhaan have been found near Rehoboth out of their normal range in an area that receives about 250 mm mean annual rainfall, where severe rangeland degradation has occurred causing the area to resemble Namib plains. This suggests that their eastern limits are not set primarily by rainfall but by habitat.

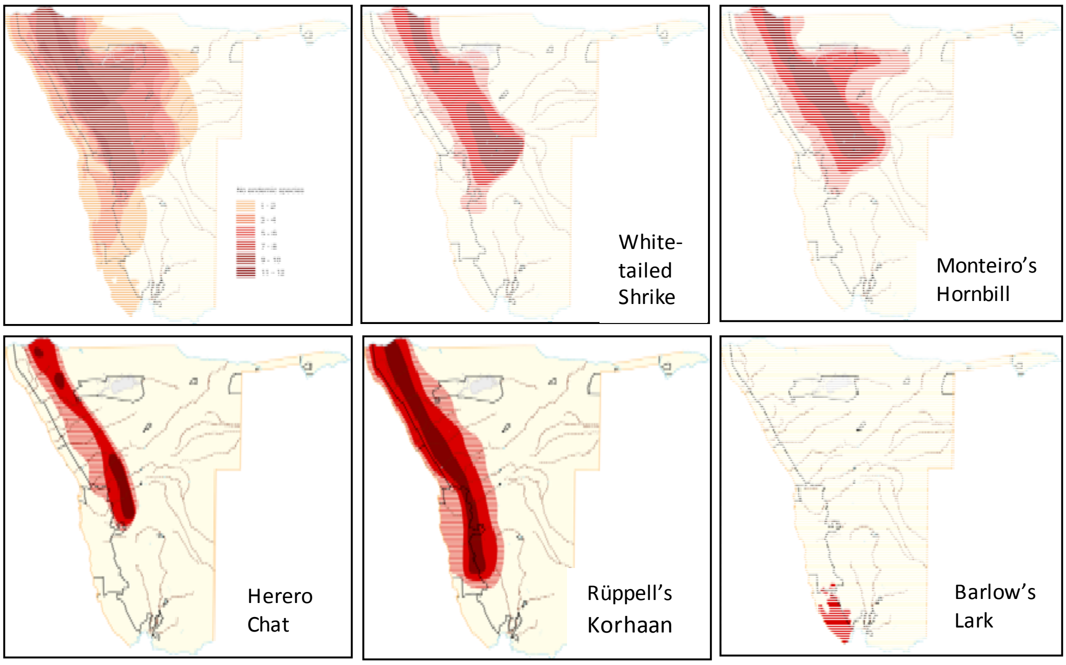


Figure 6.22. Top left – the distribution of avian endemic diversity in Namibia. The distributions of most endemic birds in Namibia are influenced mainly by vegetation, e.g. White-tailed Shrike in the escarpment belt, Rüppell's Korhaan in the Namib plains and Barlow's Lark in the Succulent Karoo. The distributions of two species are influenced mainly by rainfall, e.g. Monteiro's Hornbill, and one species, Herero Chat, mainly by altitude

Drawing on an (admittedly limited) understanding of the determinants of distribution and relative abundance in endemic birds it may be reasonable to suggest that climate change impacts on ground living endemic animals on the escarpment belt and central highlands is likely to be limited. Numbers may decline slightly and the ranges of some species may expand somewhat to the east for those species whose eastern limits are determined by rainfall. The western limits of these escarpment species are unlikely to change. The abundance of arborial species may decline with the predicted decline in woody plants of less than 2 m tall. The status of Namib endemics not dependent on coastal fog is also unlikely to change significantly. However, the status of endemics and other species that do rely on coastal fog may be at significant risk. The current constraint is that there is no credible projections on likely changes in the coastal fog situation as a result of climate change. If fog were to decline in frequency, moisture levels and distance inland that it travelled, very significant changes in the status of endemic and other species would occur. Such changes would put many species at risk of extinction. It is therefore a priority to try and understant what impacts climate change may have on coastal fog so that the likely biodiversity impacts can then be considered.

6.9 Impacts on pests and pathogens

Human health is largely determined by access to clean water, adequate food and shelter. Despite considerable improvements in rural water supply and primary health care in Namibia since 1990, there are still large disparities between urban and rural access to potable water and sanitation (WRI 2006). 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 and/or resurgent diseases. 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 allergies and asthma, are all probable (WRI 2006).

Malaria prevalence is extremely rainfall and temperature sensitive and habitat suitability for the mosquito *Anopheles gambiae* (a vector of malaria) shows a net increase in southern Africa under all three climate change scenarios referred to by Hulme (1996).

Hulme's 'core' scenario 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 some health districts in Namibia have reported increases in incidences in recent years (in Tarr 1999). Some studies indicate a four-fold increase in the size of the South African population at risk to malaria within the next ten years (Turpie *et al.* 2004). If the problem is indeed exaggerated to this degree, then the expected costs in South Africa are estimated to be in the order of R1033 million by 2010 (ibid).

A reduction in habitat suitability of the African trypanosomiasis vector as a result of climate change is also possible under Hulme's climate change scenarios (Hulme *et al.* 1996) and there is the chance that several other diseases including lymphatic filiariasis, dengue, yellow fever and cholera could infiltrate Namibia from neighbouring countries as a result of climate change (WHO/CTD 1998). However, the probability of this has neither been quantified nor qualified.

7 IMPACTS ON LAND USE AND LIVELIHOODS AND THE BIODIVERSITY IMPLICATIONS

7.1 INTRODUCTION

Although land-use is rapidly changing across Namibia, farming is still dominant in people's minds, despite the fact that it is no longer the most economically profitable use of land in many areas, or the largest contributor to the national economy. Some 70% of Namibians, including many urban dwellers, are said to practice some level of farming, and about 23% of households get their main source of income from farming. About 27% of the national workforce is in the farming sector and this figure increases to 58% for the rural workforce (Mendelsohn 2006).

Farming in Namibia is low production and high risk because of the arid conditions, the associated variability in rainfall and poor soils. Farming is directly dependent on primary production. A decline in rainfall leads to a decline in production, no matter how good the management. Poor management results in environmental degradation of the land that further reduces productivity. Environmental degradation in arid areas is difficult to reverse, and takes decades or longer. This places farmers in a vulnerable situation. The situation is exacerbated by the fact that farming systems in Namibia are near the margins of production. A decline in rainfall may lead not just to a reduced harvest, but to a total crop failure.

Most farmers in Namibia are poor and have limited ability to adapt and apply other livelihood options. The impacts of climate change may therefore be significant at the household level. Unless appropriate measures are taken to help address the situation, people's responses are likely to be driven by panic and short-term need, and may have direct impacts on biodiversity and protected areas. This section explores the likely impact of climate change on land uses outside of protected areas and the possible knock-on implications for biodiversity and protected areas.

Projections in this section are based on predicted decreases in rainfall of about 10-20% over most of the country by 2050, and 20-30% by 2080, with the greatest decreases by both dates being across the central regions. For practical application, it is assumed that a 10% decrease in rainfall will be experienced in the northern and southern regions of Namibia, and a 20% decrease in the central regions, by 2050, and that these figures will worsen to 20% and 30% respectively by 2080.

7.2 Crop production

Agriculture (predominantly irrigation of cash crops) is Namibia's major water user, consuming approximately 75% of total water demand in the country (Dirkx *et al*. 2008). Despite poor soils and considerable climatic constraints, an estimated 85% of Namibia's land surface is used for agricultural purposes (Tarr 1999). More than 90% of this land is used for livestock farming as the lack of precipitation restricts crop farming to limited areas in the north and south of the country.

Determining the effects of climate change on agriculture in Namibia is hampered by many challenges and uncertainties. These include: the future effects and extent of land degradation; the actual responses of plants (crops and rangeland grasses) to the combined effects of elevated temperatures, increased concentrations of CO_2 and increased rainfall variability; the consequences of improved cultivation practices; as well as altered social, economic and political circumstances in Namibia during forthcoming decades (Tarr 1999).

7.2.1 Dryland cropping

As a predominantly semi-arid to arid country, Namibia is on the margins of rain-fed cropping. Yet crop production (mostly millet but white maize as well) plays an important role in rural household food security, particularly in the northern parts of the country. Millet is relatively drought resistant, but if soil moisture declines as it is expected to in future decades, then declining yields, and a greater inter-annual variability in yield, are likely (GRN 2002). Reid *et al.* (2007) predict that subsistence farming will fall sharply in the country over the next four decades.

By 2050 it is predicted that only the eastern Kavango and Caprivi will be able to produce crops under rain-fed conditions (Figure 7.1).

Based on the influence of increased CO_2 and temperature alone, Namibia's maize triangle (commercially grown) and Caprivi region could experience an increase in maize yields of up to 5% under Hulme's 'core' climate change scenario (Hulme *et al.* 1996). However, if rainfall is reduced and becomes more variable, fewer areas will be suitable for cultivation.

At present, rain-fed crops in the Grootfontein- Tsumeb-Otavi triangle fail in three out of eight years. Reasonable profits are made in three out of eight years. This area is on the very margins of economically viable rain-fed crop production. It is predicted that the failure rate will increase, tipping the area over the margin of viability.

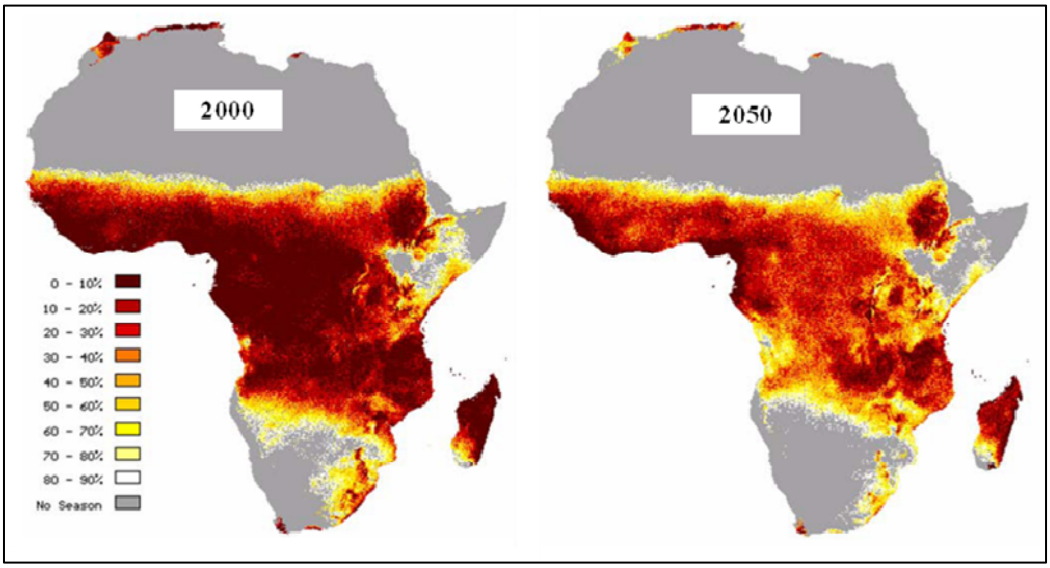


FIGURE 7.1. PREDICTED IMPACT OF CLIMATE CHANGE ON CROPPING GROWING SEASON FAILURE

7.2.2 Irrigation cropping

Commercial crop irrigation is responsible for about 50% (~160 Mm³) of national water demand in Namibia, and the Green Scheme is likely to add about another 80% (~290 Mm³) above current irrigation abstraction (Dirkx *et al.* 2008).

Most of South Africa is predicted to have a higher *relative irrigation water demand* in C-CAM's future climate scenario (Engelbrecht 2005), irrespective of its being a wet, an average, or a dry year (Schulze *et al.* 2005b). These authors show that:

- Inter-annual variability of net irrigation water requirements will increase in the north and west of southern Africa;
- Virtually all irrigated lands across the sub-region will require at least 10% more water applications per annum. Irrigated land in Lesotho (which falls within the Senqu/Orange sub-basin), may require up to 30% more irrigation applications per year – impacting considerably on Namibia as a downstream end user of the Orange river;
- The effects of climate change on the leaching of pesticides and fertilizers from irrigated land could be considerable. If it rains after a recent irrigation application then deep percolation beyond the root zone, or stormflow from the surface/near-surface is likely to take place, resulting in leaching of fertilizers and other agro-chemicals or wash-off of soil and fertilizers into the rivers. This will cause an increase in water pollution – an impact that that will threaten freshwater ecosystems and human health;

- Hulme *et al.* (1996) suggest that the growing season of maize may shift to an earlier date and, as a result of increased temperatures, shorter growing seasons and reduced yield quality are likely; and
- Altered prevalence of weeds and crop pests are also expected.

While the water demand of irrigation projects is expected to increase, a decline in surface water availability will be accompanied by fewer opportunities to develop irrigation schemes (Hulme *et al.* 1996). Along the Orange River, for example, the availability of water to Namibia may be in question (see above), as a result of both ongoing development in South Africa and climate change. It is also unclear how the changing climate will impact on the recharge and water supply of dams and aquifers. Both the Hardap and Naute dams get their water from the Fish River catchment, and the Stampriet aquifer system is part of the Aub-Olifants-Nossob catchments, all of which rise and drain the area predicted to experience the greatest reduction of rainfall as a result of climate change in Namibia. It is also important to note that the dams supplying water to Windhoek all fall into the worst affected area.

7.3 LIVESTOCK FARMING SYSTEMS

There are about 1.16 million head of cattle north of the veterinary red line fence and about 1.18 million to the south. About 300 000 head are formally marketed per year, but only about 10 000 from north of the veterinary fence (25% off-take south of the fence, <1% north of the fence). It is estimated that there is an off-take of up to 10% north of the fence through the informal sector such as local sales, roadside butcheries and own use (Mendelsohn 2006).

Allocating fixed "carrying capacity" levels for areas with highly variable climatic conditions has little practical application other than to give an indication of long-term potential, and indeed has been very damaging to Namibia's rangelands as many farmers have tended to adopt these figures as rules, resulting in overstocking in dry years and serious rangeland degradation in many areas. Carrying capacity is useful, indeed essential, when it is assessed on an ongoing basis, in real time, to determine the biomass of grazers that the rangeland will support in a particular season. However, carrying capacity alone will not ensure for healthy and productive rangelands. How the livestock is managed and the grazing routines applied, are essential components of good rangeland management. The best farmers manage for their grasses and for healthy and productive rangelands. In the context of climate change, long-term carrying capacity is a useful mechanism to explore the likely changes that may be expected. The present long-term carrying capacity for Namibia and current cattle numbers are shown in Figure 7.2.

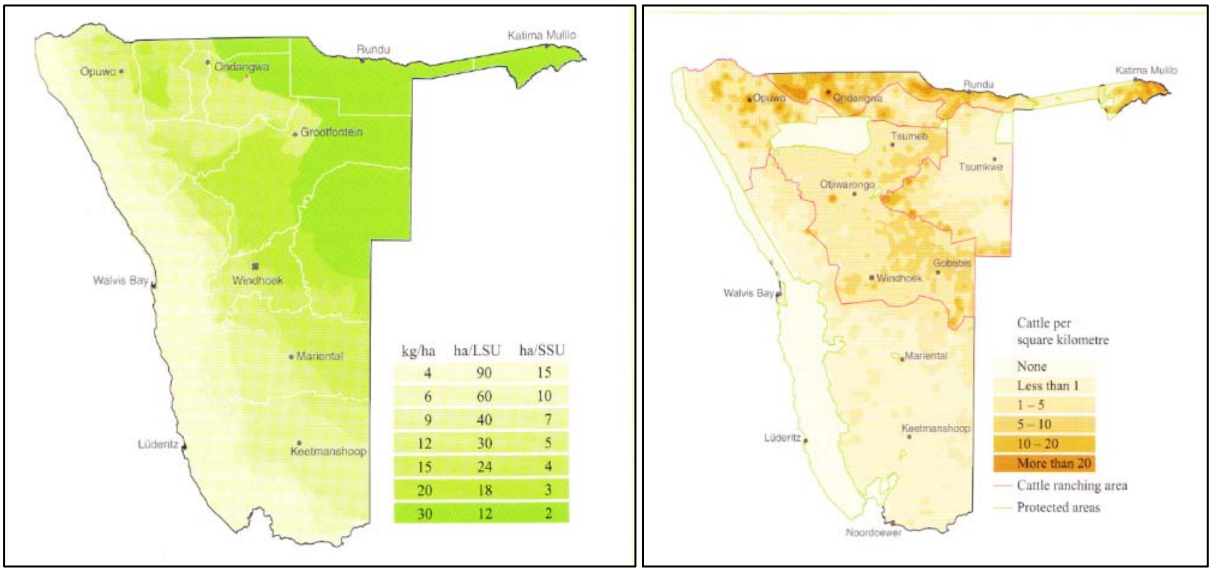


Figure 7.2. Present average carrying capacity in Namibia, and actual density of cattle. 1 Large Stock Unit (i.e. 1 head of cattle) per square kilometer converts to 100 hectare per LSU.

It is clear that, particularly in the northern mixed farming area, cattle numbers exceed long-term carrying capacity by a factor of two and more. Given that this area also supports almost 1 million head of small-stock, the long-term carrying capacity is exceeded by up to four times in places. Similar patterns are seen in parts of the Otjozondjupa and Kunene regions.

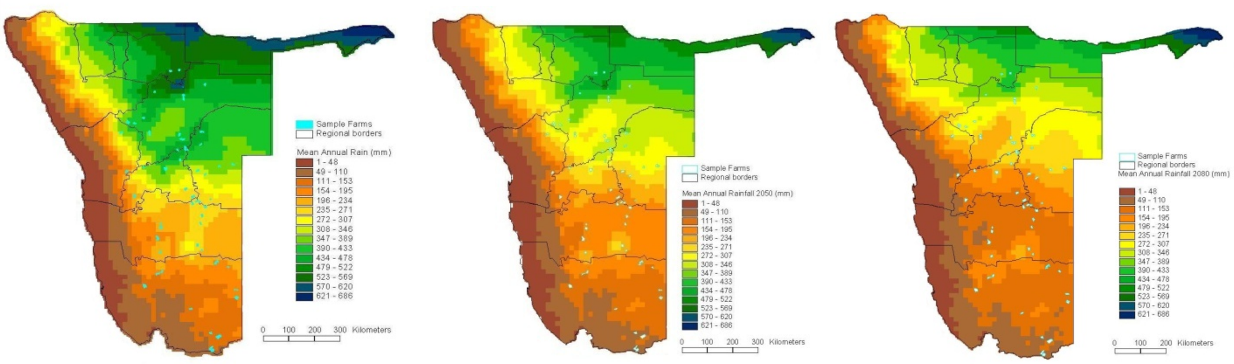
The climate change impacts on grazing and livestock health, as reported in previous studies, are expected to be severe:

- Reductions in forage quality and palatability could occur because of increasing carbon to nitrogen ratios, particularly on Namibian rangelands where low nutritional value is already a problem (Tarr 1999).
- Declining vegetation cover, which will significantly increase soil erosion (ibid).
- Midgley *et al.* (2005) determine that significant changes in vegetation structure and function are likely in several parts of the country by 2080. Vegetation will shift in spatial dominance from Grassy Savanna to Desert and Arid Shrubland. Furthermore, a reduction in ground cover and reduced Net Primary Productivity (NPP) is likely to occur throughout much of the country by 2050 (exacerbated by 2080), a situation that will have important implications for rangeland carrying capacity and livestock productivity.
- Dirkx *et al.* (2008) report that if average maximum temperatures exceed 34°C, thresholds for conception in some cattle breeds may be exceeded. Rising temperatures will reduce grazing distances and exacerbate degradation around watering points.
- With increasing aridity southern Namibia is likely to become less suited to small livestock production. This area already has low grazing value and poor stocking

rates, which have declined in recent decades - a situation that is attributed to plant species changes in response to herbivory (von Maltitz *et al*. 2005). Nevertheless, a positive direct impact of increasing temperatures could be a reduction in stock losses due to extreme low winter temperatures during the lambing season in southern Namibia (Turpie *et al.* 2004).

- Climate changes will have direct impacts on livestock morbidity and mortality.
    - Livestock plant poisonings are an important cause of mortality throughout Namibia and appear to increase after prolonged dry spells (DVS 1997).
    - Impacts on livestock are likely to include increasing heat stress and water requirements.
    - Altered geographical ranges of livestock and wildlife diseases are expected as changes in temperature and precipitation affect the distribution, the timing and intensity of both vector borne and non-vector borne diseases. Higher temperatures linked to climate change may shorten generation times and increase the total number of generations of pathogens per year for (inter alia) Anthrax, 'blackleg' (a bacterial disease), agents of *Dermatophilosis* (a fungus) and *Haemonchosis* (a parasitic worm; Dirkx *et al.* 2008). However, 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 (*ibid*).

The present and predicted rainfall patterns across Namibia are shown in Figure 7.3 below.



Current mean annual rainfall across Namibia

Mean annual rainfall across Namibia by 2050 and 2080, according to predictions generated by the HADCM3 general circulation model

FIGURE 7.3. PRESENT AND PREDICTED RAINFALL PATTERNS ACROSS NAMIBIA

A rough relationship between rainfall and carrying capacity was determined from the above maps (Figure 7.4). For each percent decrease in rainfall there is on average (across the whole rainfall gradient in Namibia) about a 1.25% decrease in carrying capacity. The relationship is not linear, however. Below about 300 mm of rainfall the ratio is about a 1.1% decline in carrying capacity per 1% decline in rainfall. At about 350 mm the ratio increases to 1.3% and above 400 mm it is about 1.6% decrease in carrying capacity per 1% decline in rainfall.

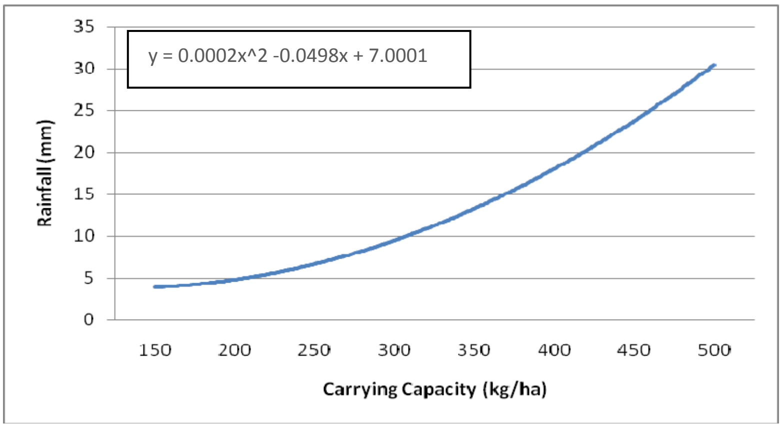


FIGURE 7.4. SMOOTHED CURVE OF THE RELATIONSHIP BETWEEN RAINFALL AND CARRYING CAPACITY IN NAMIBIA.

These ratios may become larger when other factors are taken into account, such as increased temperature, lower humidity and lower soil moisture, though there is some evidence that carbon fertilization may partly offset these impacts. Changes in carrying capacity against predicted changes in rainfall are shown in Table 7.1.

TABLE 7.1. RELATIONSHIP BETWEEN DECLINING RAINFALL AND DECLINING CARRYING CAPACITY.

Declines in rainfall (%)	Predicted declines in carrying capacity (%) in different rainfall belts (mm) in Namibia		
	100-300 mm (ratio 1.1:1)	300-400 mm (ratio 1.3:1)	400-600 mm (ratio 1.6:1)
5%	5.5%	6.5%	8%
10%	11%	13%	16%
20%	22%	26%	32%
30%	33%	39%	48%

Mean annual rainfall is also strongly linked to livestock revenue. A recent study of 58 freehold farms found that a 1% change in rainfall leads on average to a 1.36% change in revenue (Brown 2009). The expected impact of climate change on revenue of livestock farms are shown in Figure 7.5 for 2050 and 2080 against the current situation. A 10% decrease in rainfall on a low turnover farm of about 11 000 ha with an annual revenue of N$30.5.ha^{-1} in the Hardap area will result in a loss of about N$45 000 per year. A 10% decrease in rainfall on a high turnover farm of about 7000 ha in the Khomas region with an annual revenue of about N$933.ha^{-1} will experience a loss of about N$890 000 per year. A mean loss of 28% was estimated by this study by 2050 – an average loss in revenue of about N$575 000 per year per farm, and an overall loss of some N$3 billion to the freehold livestock sector. It is doubtful whether the sector will be able to bear these losses. This is on top of a steady decline in livestock numbers carried by freehold farmers over the past 40 years (Table 7.2), partly attributed to declining rangeland condition (bush encroachment and loss of perennial grasses) and competition from more lucrative and less climatically vulnerable land uses such as trophy hunting and tourism. By contrast, wildlife numbers have more than doubled on freehold land, and shown huge increases on communal areas where conservancies have been established. At the same time, tourism numbers have increased from fewer than 200 000 in 1990 to over 800 000 in 2008, and the number of trophy hunters has risen from 1918 in 1994 to over 7000 today.

TABLE 7.2. LIVESTOCK NUMBERS ON FREEHOLD LAND, 1971-2001

	1971	1981	1991	2001
Cattle ('000)	1 800	1 400	1 300	910
Decline (%)		22%	7%	30%
Overall decline (%)				49%
Small stock ('000)	4 550	4 350	3 500	2 700
Decline (%)		4%	20%	23%
Overall decline (%)				41%

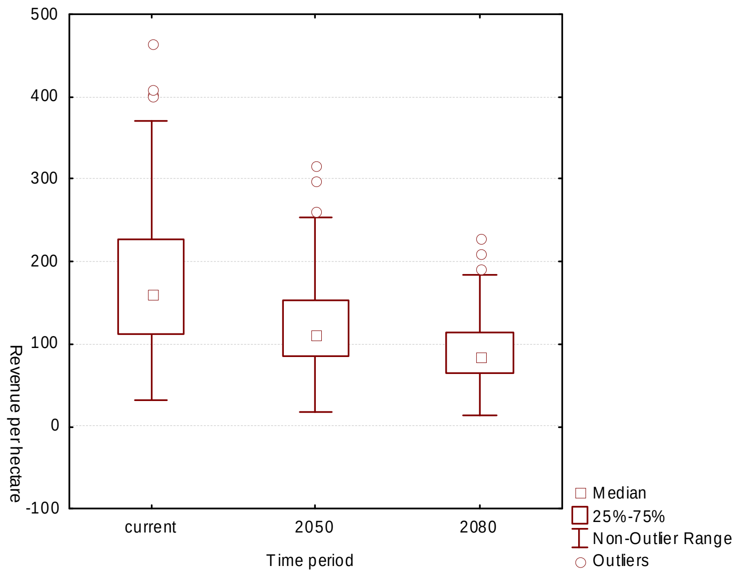


FIGURE 7.5. EXPECTED IMPACT OF CLIMATE CHANGE ON REVENUE OF LIVESTOCK FARMS

This leads to the following conclusions:

a) The productive area for large stock in Namibia will shrink towards the east and north (Figure 7.6), losing about 9 million ha by 2050 and over 18 million ha by 2080. Cattle will probably be replaced by small stock and more profitably by wildlife and tourism.

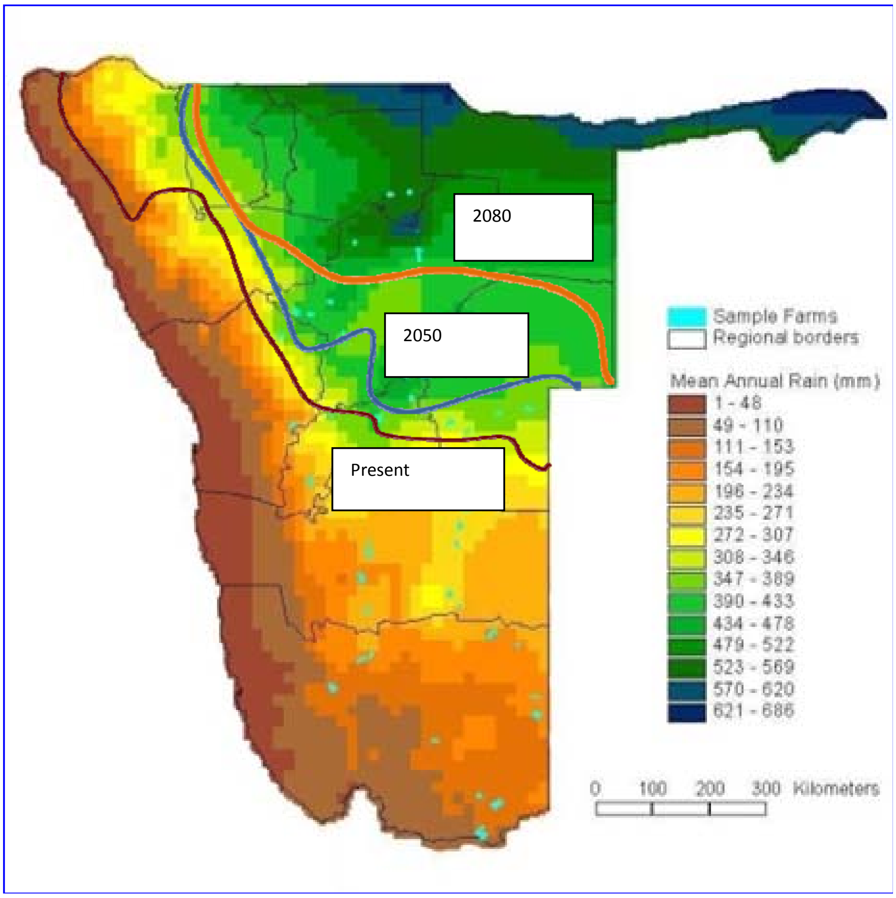


Figure 7.6. Predicted changes in the productive area for large stock in Namibia

b) The number of cattle will decline because of the reduction in prime range and in carrying capacity, and conversion to more profitable and climatically resilient forms of land use such as trophy hunting and tourism. While it is difficult to predict farmers' responses to these climatic changes, it is conservatively estimated that cattle numbers will decline to about 76% of present numbers by 2050 and 51% of present numbers by 2080 (Table 7.3).

c) Most of the loss of viable cattle farming land will occur south of the veterinary fence, and cattle numbers will decline here most dramatically – from the present 1.18 million to about 692 000 in 2050 and just 335 000 in 2080.

d) The number of cattle through formal markets will decline to about 182,823 animals (39% decline on the present 300 000) by 2050 and to 84,474 animals (72% decline) by 2080 based on the present marketing ratios north and south of the veterinary fence (25% and 1% respectively). If marketing north of the fence reaches parity with that south of the fence, then the figures will be 416,679 and 280,885 for 2050 and 2080 respectively, strong incentive indeed to address the issues of the veterinary fence, animal quality, management and marketing in the northern regions of Namibia. These figures could be further adversely affected by increased frequency and severity of droughts and floods, causing periodic crashes in cattle numbers and increasing variability in supply.

e) The amount of land that will remain viable for farming in general will decline from the present 64 million ha to 57 million ha in 2050 and 53 million ha in 2080 a decline of 11% and 18% respectively. The losses will be to the arid western and southern parts of the country, areas which have already shown that they are not viable for farming and where wildlife and scenic based tourism is rapidly expanding.

The situation for small stock farming is similar to that of cattle farming, and the same carrying capacity principles apply:

a) The productive area for small stock in Namibia will retreat from the west and expand towards the north and east into former cattle farming areas (Figure 7.7), losing about 7 million ha and gaining about 9 million ha by 2050, and losing about 11 million ha and gaining about 18 million ha by 2080, an overall increase of 2 million ha and 7 million ha respectively by 2050 and 2080.

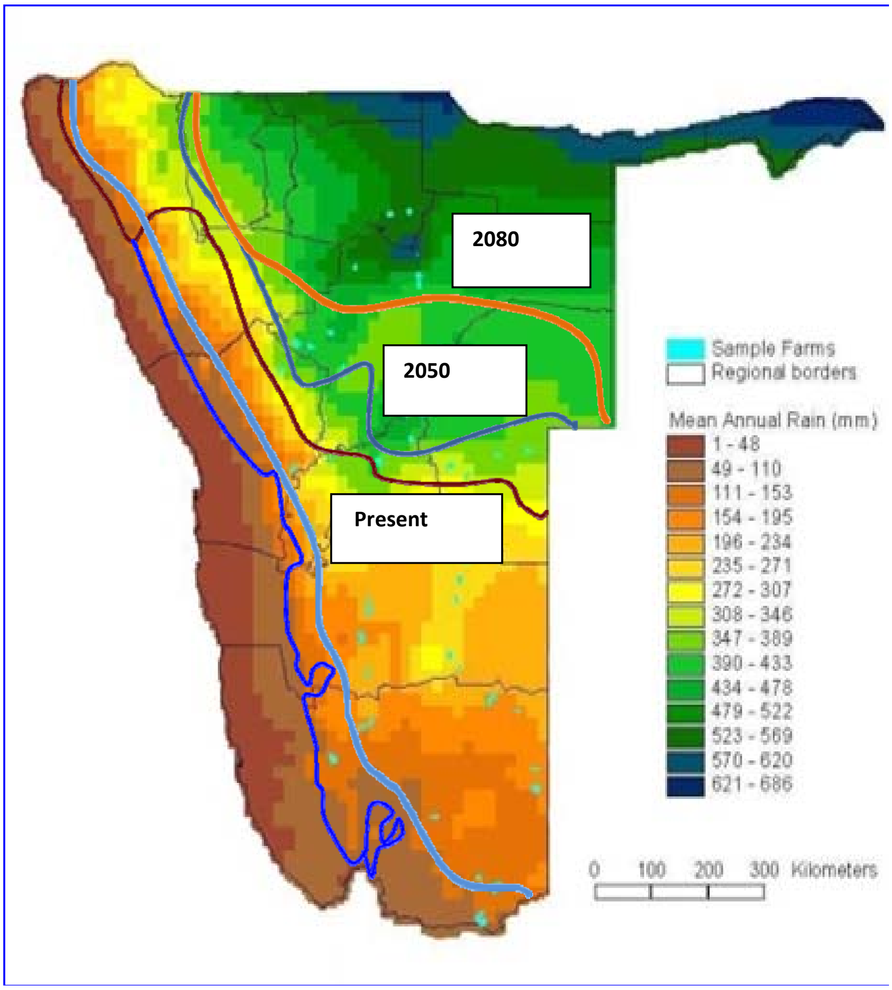


Figure 7.7. Predicted changes in the productive area for small stock in Namibia

b) Despite an overall increase in productive range and because of a reduction in carrying capacity the numbers of small stock are predicted to decline by 16% and 25% by 2050 and 2080 respectively (Table 7.3). This does not take into account any change in land use to wildlife and tourism. By comparison, cattle numbers are predicted to decline by 24% and 49% respectively.

c) The gains in land for small stock farming are mainly south of the veterinary fence.

TABLE 7.3. PREDICTED NUMBERS OF LIVESTOCK ON FARMS IN NAMIBIA IN 2050 AND 2080

Farming system	Present		2050		2080	
	Area (ha)	Cattle	Area (ha)	Cattle	Area (ha)	Cattle
Small scale mixed[10]	5 500 000	600 000	5 500 000	504 000	5 500 000	408 000
Cattle ranching[11]	31 500 000	1 400 000	22 500 000	984 000	13 500 000	524 000
Small stock[12]	27 000 000	180 000	29 000 000	172 000	34 000 000	177 000
Intensive[13]	40 000	5 000	80 000	10 000	120 000	15 000
Total	**64 040 000**	**2 185 000**	**57 080 00**	**1 670 000**	**53 120 000**	**1 124 000**

7.4 WILDLIFE AND TOURISM PRODUCTION SYSTEMS

Wildlife has increased dramatically in range and numbers across Namibia over the past 30 years. A number of factors have been responsible, the most important being the devolution of rights over wildlife by the state to freehold landowners and communal conservancies. Freehold farmers received these rights some 25 years ahead of communal conservancies. Land uses based upon wildlife and tourism in arid and semi-arid parts of southern Africa have been shown to be more economically attractive than conventional farming, and less susceptible to climatic perturbations. At the same time, Namibia has being growing as a tourism destination, both for photo-safaris and trophy hunting, and livestock production has been in decline, partly giving way to wildlife and tourism because of their economic advantages and partly because of wide-scale rangeland degradation, including bush encroachment, impacting on livestock production.

Today Namibia supports well over two million head of wildlife. Wildlife is used for tourism, trophy hunting, is sold as live animals, for commercial meat production and for own on-farm use. The combined value of wildlife use and tourism contributes about 5.5% of national Gross Domestic Product (GDP), compared to 4.5% for agriculture, 5% fishing and 6.8% mining. Only some 5% of Namibia's wildlife occurs in national parks.

[10] This assumes present relative levels of overstocking will continue. Effects of increased temperature and lower soil moisture, and greater climatic variability together with deterioration of rangelands may reduce cattle numbers yet further.
[11] This does not include any further land use conversion from cattle to wildlife management.
[12] This takes into account areas lost and gained as suitable small stock farmland and assumes the same relative density of cattle as at presently.
13 It is assumed that intensive agriculture through irrigation will grow by 40 000 ha and cattle numbers by 5 000 animals in each period.

About 10% is found on communal land and 85% on freehold land. About 80% by number are grazers. Just eight species make up over 96% by number of the grazers (Table 7.4). There is insufficient detailed data on distribution and numbers of each species, potential surplus carrying capacity for species to expand and other parameters to support a detailed analysis of the impacts of climate change on wildlife. A more general approach is adapted which looks at potential range expansion or contraction per species against their historic range and applies carrying capacity adjustment ratios as explained in the section of cattle. It makes no provision for areas that may be below carrying capacity for particular species or for land use changes from livestock to wildlife and tourism.

All else being equal, climate change impacts on the main grazing wildlife species as a result of reduced carrying capacity are predicted to lead to a decline in these species in protected areas of about 12% by 2050 and 25% by 2080. Similar declines of 11% and 22% are predicted for communal areas, and 13% and 24% for freehold areas. At the national level, a decline of 13% by 2005 and 24% by 2080 are predicted (Figure 7.8).

However, in some wildlife areas, where wildlife is below carrying capacity, the impacts may not be as severe.

TABLE 7.4. NUMBERS OF WILDLIFE IN AREAS UNDER CONSERVATION MANAGEMENT IN NAMIBIA

Species	Protected areas			Communal areas			Freehold areas		
	2004	2050	2080	2004	2050	2080	2004	2050	2080
Springbok[1]	19 932	17 341	14 750	91 070	81 052	71 035	621 561	553 189	484 818
Gemsbok[2]	8 265	7 191	6 116	30 054	26 748	23 442	350 092	311 582	273 072
Warthog[3]	209	182	155	40	36	31	173 866	154 741	135 615
Red Hartebeest[4]	1 583	1 377	1 171	700	623	546	122 805	90 876	74 911
Mountain Zebra[5]	3 974	3 537	3 100	13 242	11 785	10 329	55 520	41 085	33 867
Ostrich[6]	3 787	3 370	2 954	5 500	4 895	4 290	36 336	32 339	28 342
Burchell's Zebra[7]	18 098	15 745	13 393	20	18	16	7 303	6 354	5 404
Blue Wildebeest[8]	15 199	13 223	11 247	470	409	348	16 623	14 462	12 301
Totals	73 051	64 016	54 965	143 100	127 616	112 116	1 386 110	1 206 677	1 050 410

[1] The Springbok range may expand to the north-east, by about 3 million ha by 2050 and 4 million ha by 2080

[2] The Gemsbok range may expand into the Caprivi by about 2 million ha by 2050 and 3 million ha by 2080

[3] The Warthog range may retreat from the west and south and lose about 3 million ha by 2050 and 4 million ha by 2080

[4] The Red Hartebeest is expected to retreat from the west and south and expand towards the north-east, losing and gaining about equal areas

[5] The Mountain Zebra is not expected to change its range, although it could expand into the Otavi mountains

[6] The Ostrich is not expected to change its range

[7] The Burchell's Zebra may retreat from the west and south, possibly losing up to 7 million ha. At present they are very sparse in this area

[8] Blue Wildebeest – similar to zebra, presently very sparse in this area.

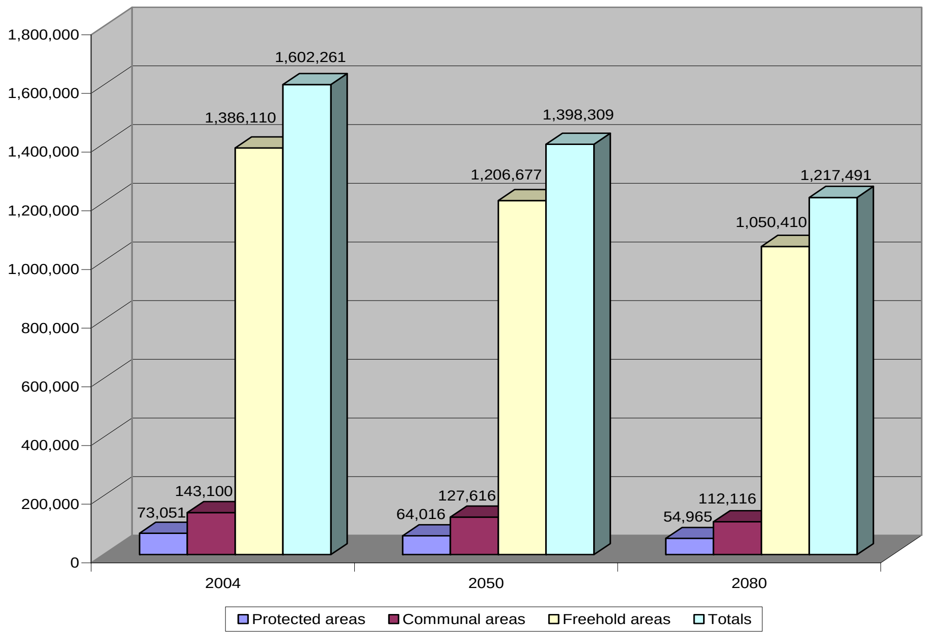


FIGURE 7.8. PREDICTED TOTAL NUMBERS OF THE EIGHT MAIN GRAZING SPECIES OF WILDLIFE (NUMBERS DERIVED FROM TABLE 7.4)

7.5 IMPACTS ON LAND USE

While climate change impacts are expected to create deteriorating conditions for cropping, livestock and wildlife, impacts on wildlife production are likely to be less severe than on agricultural production. This is likely to encourage further shifts in land use from agriculture to wildlife. This trend, in turn, is likely to lead to a growing tourism, trophy hunting, live-sale and venison sector, creating opportunities for meat producers to shift their declining livestock meat facilities to include a growing game meat industry, and possible increases in wildlife prices.

There has been an ongoing transformation of land use from livestock to wildlife and tourism in Namibia, which has seen an increase in wildlife across the country, doubling in the past 20 years, increasing numbers of trophy hunters visiting Namibia and dramatic increases in the number of tourism establishments, the vast majority on freehold land. A number of economic studies have now shown that wildlife utilization and wildlife-based tourism in Namibia generally outcompete livestock farming (Barnes & Humavindu 2003). These forms of land use are less dependent on primary production, being largely service industries. The wildlife resource base is also far better adapted to arid and highly variable conditions and the sector is not operating on the margins of viability, as is agriculture. For these reasons, many land owners and custodians consider wildlife-based enterprises to be more attractive, more resilient and less vulnerable to both current climatic variability and the looming impacts of climate change. Further deterioration in climatic conditions for farming is likely to further speed up this shift in land use.

7.6 IMPACTS ON LIVELIHOODS AND WELLBEING

7.6.1 Impacts on farmers

All these climate-related impacts are highly significant for the livelihoods and household security of farmers and their employees, for the many industries and services which are associated with farming, and for the social fabric of rural towns and villages.

The reduced viability of crop farming in communal areas will have a devastating impact on the people mainly of north-central Namibia and western Kavango. The process is likely to be one of declining crop production – more years of failure until it becomes no longer viable to plant crops. Within the Grootfontein- Tsumeb-Otavi triangle, there will be a change to small-scale irrigation. In general, there will probably be a greater focus on livestock, and where viable, a move towards wildlife & tourism business.

The main impacts of changes in rangeland conditions on people are likely to lead to pressure in communal areas to increase marketing of cattle, and thus to improve animal quality and husbandry. On freehold lands, there is likely to be a move towards more extensive, open grazing systems and group herding. In other words, there will be fewer fences.

The expected general decline in income and employment in the worst off areas will lead to:

a) increased poverty and vulnerability;
b) defaulting on AgriBank repayments, repossessions;
c) worsening income distribution with the poor getting poorer, and increased differential between rural and urban incomes;
d) impacts on health and education;
e) urban migration and informal settlement (including on resettlement farms, which are unlikely to be viable, leading to poverty traps), which could cause incomes for unskilled labour to fall by 12 to 24% in order to absorb the new workers;
f) increased dependence on government and other external support; and
g) increased lawlessness (e.g. stock theft) and social instability.

However, in some areas, transformation of land use to wildlife based industries may lead to:

a) Increased economic returns and lower impacts of climatic perturbations; and
b) Increased jobs, better pay and better career prospects.

7.7 Knock-on impacts on biodiversity and protected areas

The socio-economic impacts will have a knock-on effect on land use and management, on the surrounding environment and on biodiversity and protected areas. In communal farming areas the increased focus on livestock will lead to:

- increasing levels of overgrazing and rangeland degradation leading to further declines in carrying capacity, further poverty and greater vulnerability;
- increased burning;
- increased competition over rangelands;
- demand for rangeland tenure rights;
- pressure to shift veterinary fence; and
- demand for grazing in parks.

On freehold rangelands, it can also be expected that commercial livestock farmers will tend more towards extensive cattle-post systems with reduced fencing to adapt to the more adverse conditions. This will have a positive impact on biodiversity by improving landscape connectivity.

In irrigation farming areas, the push towards irrigation agriculture will lead to:

- greater demand for water and infrastructure, with associated impacts on river basin ecology, water quality and quantity; and
- significant abstraction of ground water.

Overall increases in levels of poverty and vulnerability will lead to:

- increased harvesting of natural resources – wild plant foods and medicines, bush meat, fish and raw materials;
- increased poaching in parks – for food and high value products (rhino horn, ivory); and
- increasing demands on MET to allow access to parks for resources, to supply wildlife and provide economic opportunities via tourism and hunting concessions.

Many of these pressures are already present, to a greater or lesser extent, because of Namibia's arid and highly variable environment and because of policy, institutional and capacity shortcomings. The projected impacts of climate change will certainly exacerbate them, some to critical levels. It is important that the impending impacts of climate change act as a catalyst to activate the necessary steps required to address key policy and mind-set issues, and to mobilise and direct political will, technical competencies and appropriate leadership.

The impacts of ongoing transformation of land use to wildlife based industries are expected to include:

- The use of land to the west and south of Namibia, which is not viable for farming, for mainly tourism, thereby creating compatible land uses along the entire length of the Namib-Skeleton Coast Park and creating ideal conditions for the establishment of landscape co-management and the establishment of a World Heritage Site; and
- A move towards more and deeper co-management approaches, open landscapes and collaboration across land holdings – for both ecological and socio-economic purposes.

From this, it is anticipated that there will be increased demand for

- wildlife for restocking with pressure on MET and protected areas to help meet the demand;
- ore secure and fuller devolution of rights to wildlife and other natural resources;
- more efficient regulatory mechanisms to allow businesses to plan and manage more efficiently with less state interference and bureaucracy;
- better and more up-to-date data and information on all aspects of the wildlife sector, including land uses, management and monitoring techniques, best harvesting practices, etc; and
- state protected areas to be used effectively as part of local economy (open fences, export resources, concessions, etc) – for both ecological and economic benefits.

In order to meet these demands, there will be a need to redress some faulty policies, such as those that currently encourage game-proof fencing, limit devolution, create inefficient bureaucracies, etc.

A significant increase is thus projected in the importance of wildlife & tourism as a land use, its growing role as a major contributor to the national economy and in the job market, and a major element in the national initiative to address rural poverty. This will significantly increase the status and importance of MET as the responsible ministry. Given the general competencies and vision within MET, this institution will fail to live up to the challenges, grasp the opportunities and drive the transformation forward in any meaningful way. Rather, they will be observers to the process at best, but probably an obstacle to the process, which will be driven by the other stakeholders. For this not to be the case, there is thus a driving imperative for MET to acquire senior staff, and to appoint appropriate office-bearers that have the necessary vision, drive and leadership to play a constructive and decisive role in the process, and ensure its smooth implementation by working closely and collegially with stakeholders and assisting to remove obstacles.

In conclusion, Namibia's climate places its farming systems on the extreme margins of viability. A relatively small deterioration in the climate will have significant impacts on agricultural production and indeed its viability. Farming is directly linked to primary production. In these dryland settings farming is not a resilient form of land use. Unless concerted, innovative and effective interventions are pro-actively applied, the socio-economic implications of climate change on the farming sector, on the rural population and on the supporting businesses and services are likely to be severe. These in turn will have significant implications for the environment, for biodiversity and for Namibia's protected areas. We are of the view that the indirect impacts on Namibia's environment, resulting from climate change impacts on farming systems, holds a far greater threat to Namibia's indigenous biodiversity and its protected areas than the direct impacts of climate change.

8 EXPECTED CHANGES IN TOURISM DEMAND

8.1 INTRODUCTION

Namibia's tourism industry has undergone rapid growth since the late 1980s, with an average increase in international arrivals of 16% per year. Recognising that tourism is the fastest growing economic sector, various promotion strategies have been set in place by the Ministry of Environment and Tourism (MET) and Namibia Tourism Board over the past few years. Tourism in Namibia relies largely on the wildlife sector and most of the tourists visiting Namibia are predominantly interested in seeing the wildlife and beautiful landscapes. Changes in the quality of wildlife viewing, wildlife numbers and in the vegetation as a result of climate change would be expected to affect the demand for wildlife tourism.

As part of this study, a survey was conducted to determine factors affecting the demand for wildlife tourism by assessing their response to various climate change scenarios. Holiday makers were interviewed in Namibian National Parks and at Hosea Kutako International Airport in Windhoek, during June – July 2009. In total, 472 questionnaires were completed. The study entailed the use of stated preference valuation methods including conjoint analysis in order to model the impacts of simultaneous changes in different attributes relating to the attractiveness of Namibia as a nature-based tourism destination.

The detailed methods of the study are reported in Appendix II, and are summarized briefly below.

8.2 FACTORS ATTRACTING VISITORS

Landscapes and wildlife were scored highest of the factors attracting visitors to Namibia (Figure 8.1). Climate as a deciding factor had an average score of 3.3 and the lowest score was the quality of fishing/hunting.

Nature attractions contributed 80% on average to tourist enjoyment. Of all the nature attractions listed, the landscapes, wildlife viewing and seeing the "Big 5" contributed most to visitor nature-based tourism experience whilst in Namibia (Figure 8.2). Seeing the Namibian specials and fishing or hunting had smaller contributions to visitor enjoyment. There was no difference found between the SADC and non-SADC visitors for enjoyment and satisfaction gained from their trip.

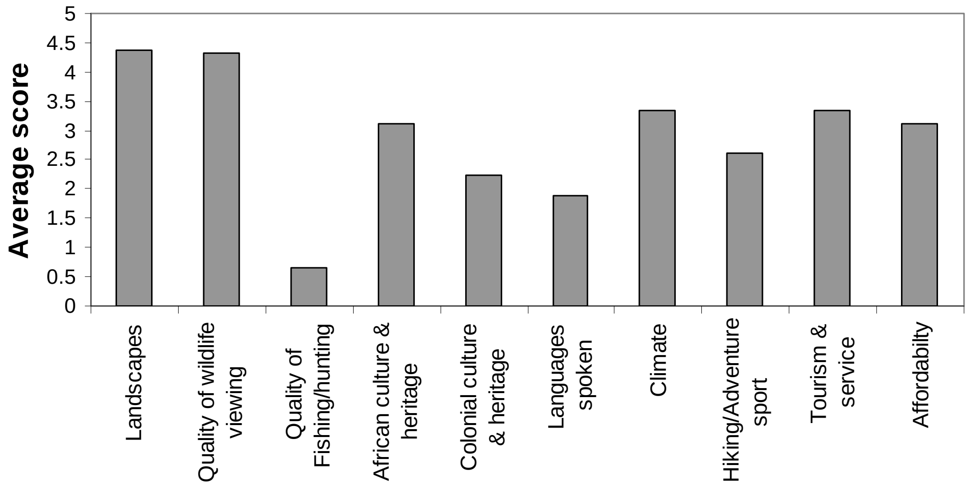


FIGURE 8.1. THE AVERAGE SCORE GIVEN BY VISITORS FOR EACH OF THE ATTRACTION FACTORS. THE RATING SCALE USED: 0 = NOT AN ATTRACTION TO 5 = A CRITICAL DECIDING FACTOR.

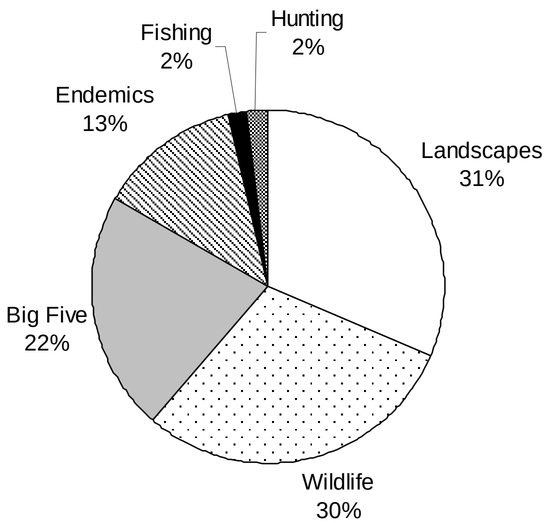


FIGURE 8.2. RELATIVE CONTRIBUTION OF DIFFERENT ATTRACTIONS TO THE NATURE-BASED TOURISM VISITOR EXPERIENCE

8.3 VALUE FOR MONEY OF PARKS AND CURRENT WTP

The majority of respondents felt that the parks were good value for money, but not excellent value, and as expected, foreign visitors were more satisfied than regional tourists. If visitors thought parks were high value for money then it would be expected that they would tolerate some loss in biodiversity. However, if value for money is not considered to be very good then a negative response regarding the degeneration of the product (e.g. quantity of wildlife) might be expected.

8.4 MODELLING TOURISM DEMAND

Respondents were each asked to score five future scenarios, with a total of 16 scenarios scored in the various versions of the questionnaire. The scenarios described possible futures in terms of biome distribution (), the percentage of current wildlife and Namibian specials remaining and temperature (either no change or a 3 C increase).

The utility score (Z), was predicted on the basis of the attribute levels generated by a general linear model as follows:

$$Z = 2.23 + (0.52 \text{ if } VegA \text{ or } -0.38 \text{ if } VegC) + 2.51\, Wildlife + 2.46\, Specials,$$

where *Veg A* and *Veg C* are biome scenarios (Figure 8.3), *Wildlife* and *Specials* are expressed in terms of percentage of present day numbers.

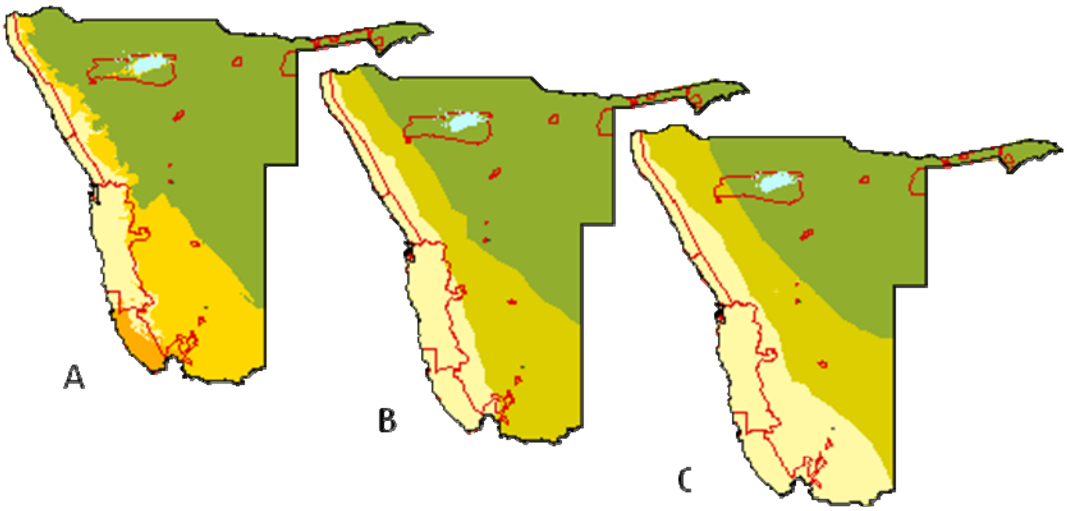


FIGURE 8.3. HYPOTHETICAL SCENARIOS OF CHANGES IN THE DISTRIBUTION OF BIOMES PRESENTED TO RESPONDENTS

Based on visitors stated response to selected scenarios in terms of how they would have changed the amount of time spent in Namibia, a model was developed as follows (r^2=0.97):

$$\%time = 48.1 + 6.66 * Z,$$

where *%time* is the expected percentage of current trip length.

8.5 Climate change impact on tourism

Using these relationships, and the expected changes in biodiversity described in earlier sections, it was estimated that climate change could reduce nature-based tourism demand by as much as 15%. This is a smaller percentage change than the expected changes in wildlife. However, it would be expected that tourism would be relatively resilient, especially given the high contribution of landscapes to the visitor experience which will not be significantly impacted by climate change.

In reality, the loss of interest from the current type of visitors may be compensated by increased interest from other groups, such as adventure tourism. At present these are relatively minor in comparison to mainstream nature-based tourism, however, so the compensation may only be slight.

9 EXPECTED CHANGES IN ECONOMIC OUTPUT

In this section the impact of likely climate change on carrying capacities for livestock and wildlife, and on tourist visitor numbers, as described in the analysis above is assessed. The measure of economic value is the direct contribution of land and resources to the gross national income (GNP). The impact is assessed in terms of how much of the base line direct GNP values, as measured above, will change by 2080 as a result of the climate change predictions. It is noteworthy that this analysis is done by superimposing the 2080 setting after climate change on current land use. It does not take into consideration autonomous adaptations that are expected to happen, or adaptations resulting from policy interventions, or changes in population growth, which will happen between the present and 2080.

The challenge was to convert the predicted changes in physical livestock, wildlife, and tourist numbers, referred to above, into changes in GNP contribution. For this we used detailed spreadsheet enterprise models for livestock, tourism and natural resource use activities. These empirically-based budget and cost-benefit models measure among other things the annual direct contribution to GNP. With the use of sensitivity analysis the impacts of changes carrying capacity, tourism numbers, and output on GNP contribution can be measured. Specifically, the models on land use developed by Barnes *et al.* (2010) were used. The latter study used enterprise models for eleven different land uses, examining communal and commercial land livestock systems and non-consumptive tourism systems. Results of the sensitivities on these models are shown in Appendix IV.

Changes in livestock and wildlife numbers predicted above are complicated, by the fact that wildlife numbers are currently in the process of increasing and livestock numbers are in the process of decreasing. The analysis assumes that the current stock numbers apply. Reduced carrying capacity and shifts in land suitability mean, that large stock numbers will be particularly hard hit by climate change. The analysis above indicates that, nation-wide, numbers of cattle in fenced ranches can be expected to decrease to as low as 40% of current levels 2080. Numbers of communal livestock (small-scale and cattle post systems) can be expected to decrease to as low as 70% of current numbers by 2080. Small stock, mostly in commercial areas will tend to expand to the north and numbers of small stock can be expected to remain around 100% of present numbers.

An analysis of the likely impact of climate change on the gross incomes of livestock and trophy-hunting landholders in the commercial land was carried out by Brown (2009). She used regression analysis on questionnaire returns for a sample of 60 commercial farmers, to get farmer perceptions on how their incomes would be affected in the face of climate change scenarios, similar to those identified in this study. For fenced commercial livestock production it was estimated that gross incomes would decline to some 40% of current levels by 2080, and trophy hunting gross incomes would decline by more. Trophy hunting is more profitable, as an enterprise, than livestock ranching, and a drop in gross income means less in terms of a drop in net returns for trophy hunting, than is the case with livestock. For this analysis it is assumed that the expected changes in livestock numbers given above will be reflected on the gross outputs for the different livestock production systems.

As described in Chapter 4, non-consumptive tourism makes up some 80% of the total nature-based tourism value. Wildlife contributes some 50% of the GNP value of non-consumptive tourism. The rest is attributable to attractions, such as scenery, not impacted specifically by climate change. The demand function derived from the protected area tourism survey data (described above), indicates that, nation-wide, the numbers of tourist visits will be likely to drop to some 85% of what they would otherwise have been by 2080, as a result of climate change.

Numbers of grazing wildlife species, (the bulk of current wildlife biomass, particularly in the commercial areas) are expected to decrease to about 75% of current levels. Disregarding expected growth in wildlife numbers in under-utilised areas the gross output for other (non-tourism) wildlife use can also be expected to drop to 75% of current levels by 2080. Wild Plant use, although highly valuable and suffering locally from depletion, is generally well under the national potential for use of these resources (Barnes *et al.* 2005). The uses are mainly carried out for essential communal land household livelihood strategies. Disregarding the fact that these uses are likely to increase as other options through agriculture are diminished, it was assumed for this impact analysis that the gross outputs for these activities would remain at 100% of current levels by 2080. Similarly, inland fish production was treated as remaining at 100% of current levels by 2080.

Based on the predicted trends described in previous sections, it was assumed that dryland cropping would be almost eliminated but that this would be compensated by irrigated crop production in which a lot of resources will be expended despite scarcity of water and poor financial viability. Overall, it was assumed that dryland crop gross output would decline to some 25% of current levels.

Irrigated production will attain more importance, and indeed it is currently part of an ambitious expansion programme. However increasing demand for decreasing surface flows particularly in Orange and Fish river systems in the south central broad integrated region will constrain development. These southern irrigation schemes are most viable, and expansion related to the Kavango, Zambezi and Kunene river systems in the north east and north-west broad integrated regions, will be constrained by financial and economic viability problems. It is therefore assumed that despite increasing demand for irrigation development, the value added to GNP by irrigated agriculture will not grow but would remain at 100% of current levels by 2080.

Estimated economic losses were highest for the livestock sector (N$2 035m), and in particular for commercial fenced ranching (Table 9.1). This is a result of the fragile financial and economic viability of this system, where a small drop in income results in a devastating loss in net income. In terms of long term adaptation it means that medium to large scale livestock farming systems will tend towards becoming lower input in nature, with systems closer to the cattle posts of the communal lands rather than ranches.

TABLE 9.1. ESTIMATED LOSSES IN DIRECT GROSS NATIONAL PRODUCT CONTRIBUTED BY AGRICULTURAL PRODUCTION AND NATURAL RESOURCE USES IN 2009 VALUES (N$ MILLION)

Region	North West	Central South	North East	Total
<u>Agriculture</u>				
Livestock				
State land	0	0	0	0
Communal land	44	10	16	70
Commercial land	786	590	590	1 965
Total	830	600	605	2 035
Crops				
State land	0	0	0	0
Communal land	72	0	46	118
Commercial land	0	0	19	19
Total	72	0	65	137
Total agriculture				
State land	0	0	0	0
Communal land	116	10	61	188
Commercial land	786	590	609	1 985
Total agriculture	**902**	**600**	**670**	**2 172**
<u>Natural resources</u>				
Tourism				
State land	46	16	3	65
Communal land	10	5	1	15
Commercial land	57	57	76	190
Total	112	78	80	270
Wildlife (other)				
State land	13	4	1	18
Communal land	2	1	0	4
Commercial land	10	10	14	35
Total	25	16	15	57
Wild plants				
State land	0	0	0	0
Communal land	0	0	0	0
Commercial land	0	0	0	0
Total	0	0	0	0
Fish (inland)				
State land	0	0	0	0
Communal land	0	0	0	0
Commercial land	0	0	0	0
Total	0	0	0	0
Total natural resources				
State land	58	21	4	83
Communal land	12	6	1	19
Commercial land	67	67	90	225
Total natural resources	**138**	**94**	**95**	**327**

Losses in the cropping sector were predicted to be in the order of N$137m. Income from natural resources use is expected to be more resilient in the face of climate change, given the generally lower reliance of these activities on primary production and rangeland carrying capacity, with total losses of about N$327m. In total climate change was estimated to reduce land-based economic outputs by a total of just under N$2.5 billion per annum (in 2009 values) by 2080. This does not include other costs such as those associated with deterioriation in social systems and health.

TABLE 9.2. ESTIMATED LOSSES IN DIRECT GROSS NATIONAL PRODUCT (GNP) CONTRIBUTED PER KM^2 BY AGRICULTURAL PRODUCTION AND NATURAL RESOURCE USES IN 2009 VALUES (N$)

Direct GNP (N$ per hectare, 2009) **Region**	**North West**	**Central South**	**North East**	**Total**
Agriculture				
Livestock				
State land	-	-	-	-
Communal land	2.66	0.63	9.03	2.02
Commercial land	31.70	83.20	166.40	55.47
Total	17.19	21.54	96.64	24.70
Crops				
State land	-	-	-	-
Communal land	4.40	-	26.44	3.41
Commercial land	-	-	5.48	0.55
Total	1.50	-	10.41	1.67
Total agriculture				
State land	-	-	-	-
Communal land	7.06	0.63	35.47	5.43
Commercial land	31.70	83.20	171.88	56.01
Total agriculture	**18.68**	**21.54**	**107.05**	**26.36**
Natural resources				
Tourism				
State land	6.46	3.76	3.29	5.26
Communal land	0.60	0.28	0.44	0.44
Commercial land	2.30	8.04	21.43	5.36
Total	2.33	2.79	12.77	3.28
Wildlife (other)				
State land	1.78	1.03	0.91	1.45
Communal land	0.15	0.07	0.11	0.11
Commercial land	0.42	1.48	3.95	0.99
Total	0.53	0.58	2.41	0.69
Wild plants				
State land	-	-	-	-
Communal land	-	-	-	-
Commercial land	-	-	-	-
Total	-	-	-	-
Fish (inland)				
State land	-	-	-	-
Communal land	-	-	-	-
Commercial land	-	-	-	-
Total	-	-	-	-
Total natural resources				
State land	8.24	4.79	4.19	6.71
Communal land	0.75	0.34	0.54	0.55
Commercial land	2.72	9.52	25.38	6.35
Total natural resources	**2.85**	**3.37**	**15.17**	**3.96**

10 ADAPTATION OPTIONS AND THEIR ECONOMIC FEASIBILITY

10.1 INTRODUCTION

Responses to climate change include mitigation measures and adaptation measures. Mitigation measures are interventions to reduce the sources or enhance the sinks of greenhouse gases. Adaptation measures involve adjustment in natural or human systems to a new or changing environment. These can be anticipatory or reactive, private or public, autonomous or planned. With the likely minimum global warming of 1.8°C over this century (IPCC 2007), some significant and unavoidable portion of the risk of climate change cannot be lowered by greenhouse gas emissions reduction, i.e., mitigation. For these expected near-term damages, adaptation to climate change is the only possible policy response (Fagenhauer 2006).

Given that Namibia is an insignificant contributor to greenhouse gas emissions, but is highly vulnerable to the impacts of climate change, the country's policies and institutions must focus on achieving appropriate adaptations so that ecological processes can be maintained, people's lifestyles are secure and the economy can prosper. Thus, adapting to climate change to prevent and/or reduce the potential negative impacts of climate change is a stated high priority for Namibia. It is essential to understand the potential implications of climate change for Namibia, where water demand is already projected to exceed extraction capacity by 2015 (Newsham & Thomas 2009).

Adaptation responses can be reactive or proactive (Table 10.1). Adaptation to Climate Change in Namibia has largely been reactive thus far, as evidenced by crisis-driven drought or flood relief efforts, defending seafront infrastructure, etc. This policy approach is often termed "maladaptation" (Burton *et al.* 2006). A proactive approach aims to reduce exposure to future risks, for instance by avoiding development on flood-prone lands (e.g. Cuvelai system and Zambezi floodplains).

Namibia faces a host of difficult issues stemming from the underlying characteristics of climate risk, the institutional contexts for adaptation decision-making and action, and inherent limits on available resources—all compounded by politically sensitive questions of responsibility and equity. These include:

- the appropriate balance between "reactive" and "proactive" approaches;
- the proper coupling of specific adaptations and stronger adaptive capacity;
- the difficulty of distinguishing climate change impacts from those due to natural climate variability; and
- adaptation's intersection with a broad range of other policy areas and priorities.

Table 10.1 Adaptation response options (Adapted from UNFCCC 2007)

	Reactive	Anticipatory
Agriculture	• Erosion control • Dam reconstruction • Changes in fertilizer use & application • Introduction of new crops • Soil fertility maintenance • Altering planting & harvesting times • Educational outreach programs on conservation & management of soil & water	• Development of resistant crops to aid food security • Research and development • Soil and water management • Diversification & intensification of food & plantation crops • Policy measures, tax incentives & appropriate subsidization • Development of early warning systems
Water	• Protection of groundwater resources • Improve management & maintenance of existing water supply • Groundwater & rainwater harvesting & desalinization	• Efficient use of recycled water & grey-water harvesting • Conservation of water catchment areas • Improved system of water management • Water policy reform including pricing and irrigation policies
Forestry	• Improvement of management systems including deforestation, reforestation & agro-forestry • Promoting agro-forestry to improve forest goods & services • Development /improvement of national forest fire management plans • Improvement of carbon storage in forests	• Extension of protected areas and biodiversity corridors • Identification / development of species resistant to climate change • Improve assessment of ecosystem vulnerability • Monitoring of species • Development & maintenance of seed banks • Forest early warning systems
Coastal & marine resources	• Protection and conservation of coral reefs, mangroves, sea grass & littoral vegetation	• Better coastal planning & zoning • Development of legislation for coastal protection • Research & monitoring of coasts & coastal ecosystems

With the inherent uncertainty surrounding predicted climatic shifts and their concurrent impacts, **the most effective adaptation response will be to ensure that environmental management policies in general are robust**, promoting best practise and preparedness across all sectors. In addition, there may be **specific actions** required to address the predicted direct and indirect impacts on biodiversity.

In this section, options for addressing the direct and indirect impacts on biodiversity and the protected area system are presented and discussed. The economic viability of introducing specific adaptation measures is also explored and discussed. Finally, environmental management institutions and policy are analysed in terms of their general robustness and suitability for implementing these measures.

10.2 Specific options for reducing direct impacts on biodiversity

Options for addressing different climate change impacts on biodiversity are summarized in Table 10.2 and discussed in more detail below.

Table 10.2. Options for reducing direct impacts on biodiversity

Climate change impact	Adaptation
Shifts in distribution and migration routes; **shrinking ranges** of endemic species	• Shift to a landscape approach to conservation, including shifts and expansions in protected areas, increasing connectivity through encouragement of conservancies and co-management and removing fences, and fostering cross-border cooperation for biodiversity management • Ex situ conservation – seed/gene banks
Loss of ecosystem services	• Conservation targets described above should take this into account
Bush encroachment, loss of open habitats	• Promote charcoal production, compressed fuel blocks, harvesting wood for power production • Grazing/browsing and fire management practices
Uncertain future	• Monitoring and early warning systems

10.2.1 Increasing size and connectivity of the conservation network

Introduction

As part of this study, a conservation planning study was conducted to assess the way in which the conservation network (taken to be the state protected areas and surrounding conservation areas on communal and freehold land) would need to be adapted to maintain its mandate under a climate change scenario. The study is reported in detail in Appendix II and summarized here.

Achieving adaptation to the impact of climate change is defined here as "facilitating the continued ability of the conservation network to meet conservation targets". Conservation targets are used in conservation planning as quantitative interpretations of our conservation goals. Defining conservation targets is optimally performed on the basis of the best available scientific information, expert advice and international best practice. Therefore targets provide a useful means with which to measure the effectiveness of a conservation network in terms of meeting its mandate both in the present and under future conditions, and for our purposes here provide a quantitative measure of the ability of the conservation network to "buffer" the impacts of climate change by continuing to meet these targets.

Determining whether a conservation network has the ability to meet conservation targets now and into the future is limited by the availability of suitable data. Data are not only required on the current distribution of biodiversity, but more importantly are also required for the projected future distribution of biodiversity. For this study two excellent data sources were used:

1. A vegetation-based Adaptive Dynamic Global Vegetation Model (aDGVM) dataset for southern Africa created by Scheiter and Higgins (2009) that predicts changes in 2080 in vegetation structure and biomass production over the sub-continent; and,
2. A species-based model dataset created by Broennimann *et al.* (2006) that projects the changes in 2080 in species distribution for 975 endemic southern African plant species.

Targets defined for this study were 15% of the original extent of all vegetation types and agricultural land types, 50% of the original extent of south-facing slopes (which are assumed to act as refugia in arid landscapes), and 10% of the area of occupied by each species (using occurrence in planning unit as a surrogate). In addition, because of the relative unreliability of species distribution projections, we introduced primary production (PP) as a novel target in this study in order to evaluate the performance of the conservation network under climate change. We set the target as either being equal to the sum of primary production in the conservation network at present, or as being equal to the proportion of regional PP held in the conservation network at present. The rational for this is that primary production is expected to change over much of the existing conservation network. Adjusting the conservation network to maintain current levels of primary productivity is assumed to maintain the same level of abundance of wild plant and animal populations because of its relationship to carrying capacity (e.g. Desmet 2004, Berliner & Desmet 2008). Note that this does not necessarily look after species who are narrow in their habitat requirements or less able to shift their distributions.

The planning domain (viz. Namibia) was divided into 10 788 equal-size 9 x 9km conservation planning units (PU). The minimum size of the PU was limited by the scale of the species input data. PUs that were more than 40% transformed were excluded form from the analysis. For future scenarios PUs excluded due to urban areas were expanded by one PU to take into account likely expansion in major urban areas between now and 2080.

For the purposes of the primary productivity analysis the country was divided into 12 broad bio-climatic eco-regions based on biomes and basic geo-morphological regions (Figure 10.1). The rationale for this subdivision was to provide a coarse national-level stratification of the country with which to test the representivity of the conservation network in terms of capturing an equal proportion of each region's PP.

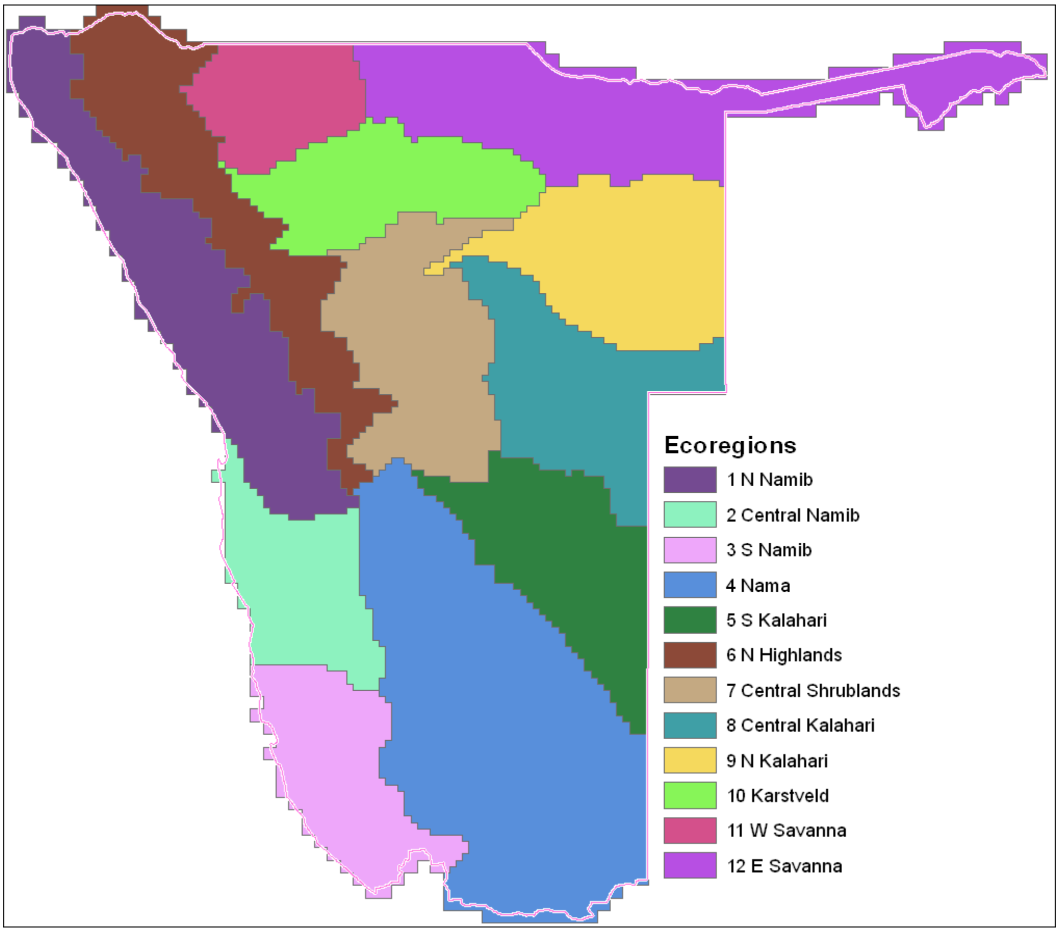


FIGURE 10.1. BROAD ECOREGIONS USED TO SUMMARISE PP DATA IN THIS ANALYSIS.

Current level of protection

The conservation network covers 45% of the country or approximately 37 million ha (Table 10.3). Privately/communally owned conservancies comprise nearly 60% of the conservation network, though they cannot be assumed to be as efficient in their conservation outcome. Thus it is important to consider both the core conservation area (comprising state protected areas) as well as the important role played by the surrounding lands under wildlife uses.

TABLE 10.3. A SUMMARY OF THE PROPORTIONAL COMPOSITION (% OF TOTAL CONSERVATION NETWORK AREA) OF PA CATEGORIES AND OWNERSHIP TYPES MAKING-UP THE NAMIBIAN CONSERVATION NETWORK

PA Category	Ownership				Total
	Emerging	Gazetted	Private	State	
Commercial conservancy	0	0	13.4	0	**13.4**
Communal conservancy	10.1	35.8	0	0	**45.8**
Community forest	0	1.1	0	0	**1.1**
Private nature reserve	0	0	1	0	**1**
Protected area	0.3	36.6	0	0	**36.9**
State concession area	0	0	0	1.8	**1.8**
Total	**10.3**	**73.4**	**14.5**	**1.8**	**100**

As a proportion of the country Namibia probably has one of the largest conservation network of any country globally. Only 2% of biodiversity features targeted are not represented within the conservation network at all, and a total of 5% fall short of their target. We can conclude that currently the Namibian conservation network is representative of the majority of the country's biodiversity. However, there are some notable gaps in the conservation network:

1. In the north of the country targets for the vegetation and land-types of the Cuvelai drainage system cannot be achieved. Based on the land-cover data available this ecosystem has been almost entirely transformed and there is less natural vegetation remaining than the target set (i.e. the ecosystem is greater than 85% transformed). This is the only highly transformed or "critically endangered" landscape in Namibia.
2. The south of the country especially the SE (Nama Karoo and Orange River valley) is the most poorly represented in the conservation network and consequently the area where most outstanding targets are to be met.

Addressing these gaps in the conservation network will require (Figure 10.2):

1. Expansion and consolidation of existing reserves particularly in the north where this strategy can meet all targets.
2. Creation of new reserves particularly in the SE Kalahari, Nama Karoo and eastern Orange River valley regions.

The conservation network currently captures 42.5% of the country's primary productivity. However, this is not evenly spread across the country, with the southern Kalahari and Nama bioregions being underrepresented (Table 10.4).

TABLE 10.4. THE PROPORTION OF REGIONAL PRIMARY PRODUCTION REPRESENTED IN THE CONSERVATION NETWORK

Region	Outside	PAs
1 N Namib	11.46	88.54
2 Central Namib	26.86	73.14
3 S Namib	21.23	78.77
4 Nama	87.97	12.03
5 S Kalahari	99	1
6 N Highlands	35.35	64.65
7 Central Shrublands	55.83	44.17
8 Central Kalahari	68.33	31.67
9 N Kalahari	28.53	71.47
10 Karstveld	58.95	41.05
11 W Savanna	56.1	43.9
12 E Savanna	76.7	23.3
Total	**57.5**	**42.5**

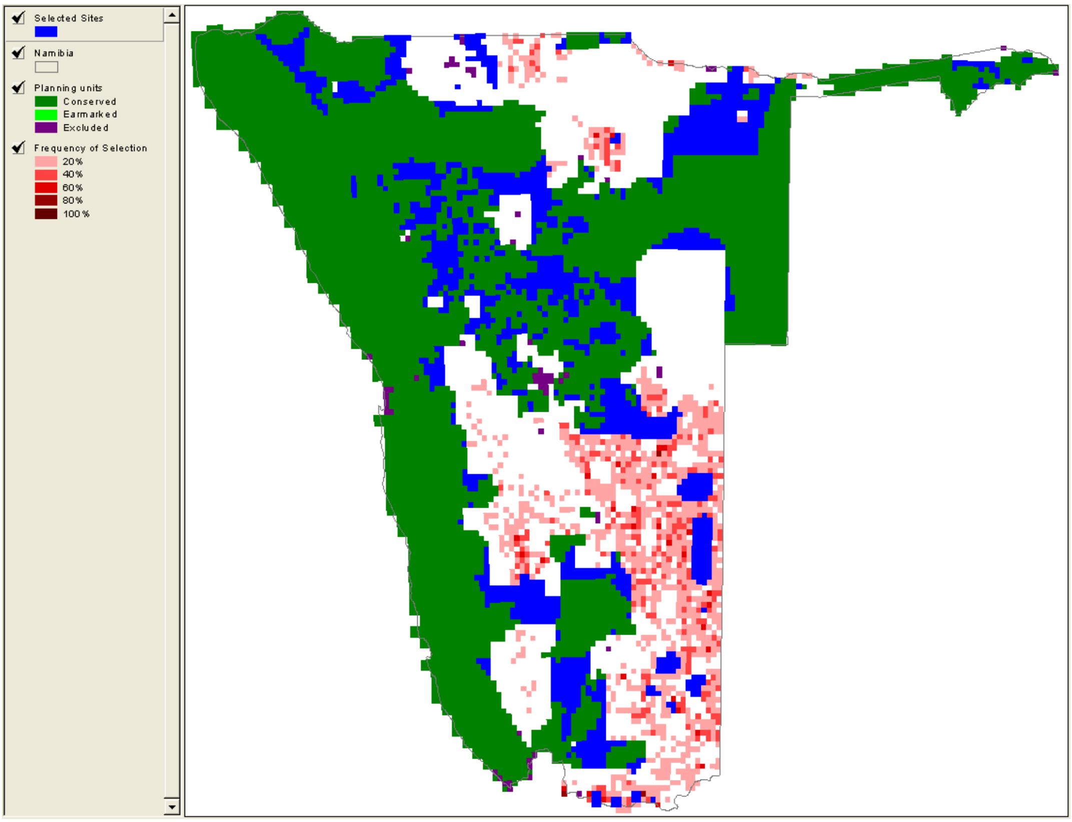


FIGURE 10.2. THE MINIMUM SET OF SITES SELECTED (BLUE) TO MEET ALL BIODIVERSITY TARGETS IN THE PRESENT CLIMATE AS WELL AS MIMINUM COST AND BOUNDARY LENGTH

Accommodating species range shifts

Since Namibia is rich in species adapted to warm, dry conditions, the south and south west parts of the country are predicted to see the greatest increase in total species numbers as well as the lowest proportion of species loss, whereas much greater losses are expected to be experienced in the central, northern and eastern areas (Midley *et al.* 2005). At least 7% of plant species modelled are estimated to shift their distribution range out of Namibia entirely with 52% of species showing range contractions and 41% showing range expansions. It should be noted, however, that the assumptions underlying these predictions are untested.

Deciding on an approach to setting targets to assess how well the current conservation network meets targets for the future distribution of species is not trivial. In this study we targetted the area equivalent of 10% of the *future* predicted range of each species. Currently the conservation network achieves 99.7% of targets for species (854 out of 856 species current targets achieved). The current conservation network is also effective at achieving future targets for plant species - 848 out of a total of 856 (99%) species future targets are achieved by the current conservation network. Mopping-up outstanding future targets is not spatially efficient and would require between a 20-30% expansion of the conservation network to meet targets for all species. Most of this expansion can be achieved by expanding existing protected areas, with two notable exceptions – the eastern Orange River Valley and the southern Kalahari/Nama Karoo regions where species priorities are located away from any existing protected area (Figure 10.3).

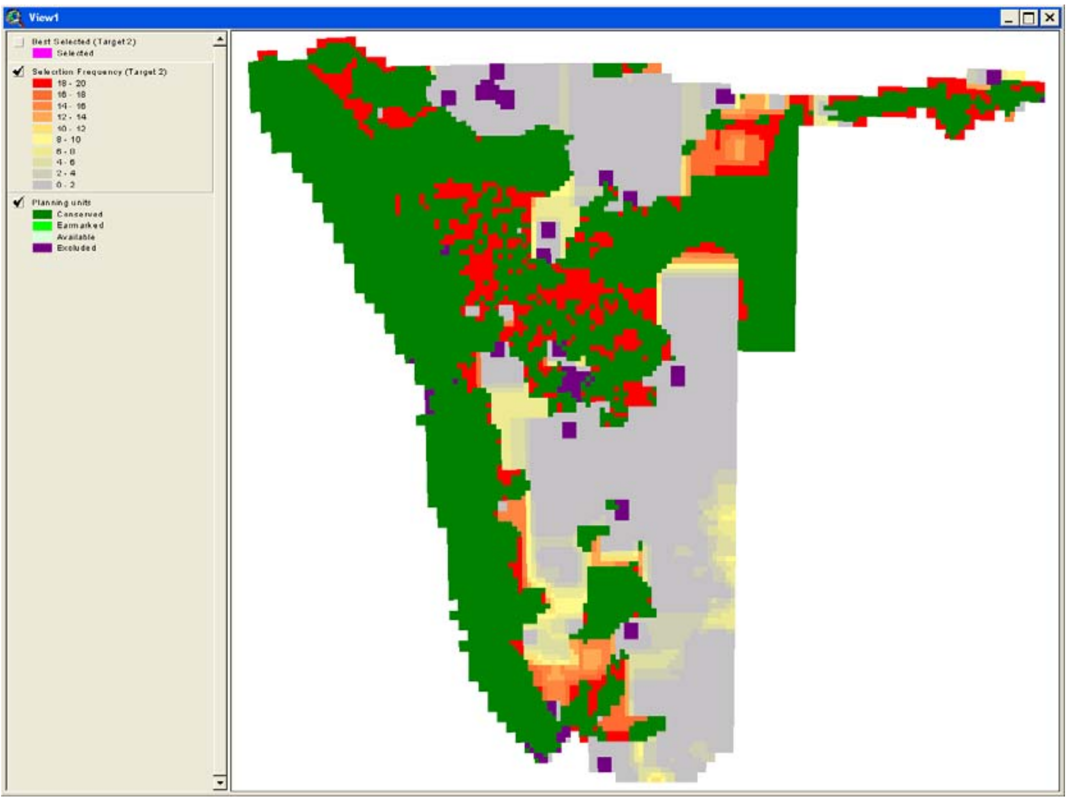


Figure 10.3. Selection frequency of sites (for 20 model iterations) in order to represent 10% of future species ranges (with a high adjacency requirement)

Expansion required to maintaining carrying capacity

Based on the observed current and future predicted PP the national total PP is predicted to decrease by 4.5% and that within the conservation network will be reduced by 4.4%. However, change is not equal across the country (Table 10.5).

Summer rainfall areas are expected to increase by as much as 30%, especially in high-lying areas. In contrast, winter and winter/summer ecotone rainfall areas in the south are expected to decrease by as much as 40%. For the conservation network (Table 10.5) this change will have significant impacts on the abilities of protected areas in the Central and Southern Namib and Nama eco-region (change >-15%) whereas elsewhere in the currently summer rainfall areas change is expected to be less severe (-5% to +5%).

This analysis considered two options – (i) maintaining current total primary productivity and (ii) increasing the system to obtain 40% of PP in each bioregion. Addressing gaps in the current conservation network to achieve future targets in PP would require between a 35-43% increase in the size of the current conservation network. Most of this expansion could be achieved by expanding and consolidating existing PAs with notable exceptions in the south of the country particularly the southern Kalahari where there are currently no PAs (Figure 10.4). Consolidation of the conservation network into three major bioregional corridors would also contribute significantly to the maintenance of macro-ecological climatic gradient corridors. These corridors are the:

1. North-south escarpment/Namib corridor (existing)
2. West-east Kaokoveld-Caprivi corridor (existing)
3. West-east southern Namib-Kalahari corridor (not existing)

Table 10.5. The percentage change in conservation network total primary production (relative units) summarised per eco-region.

Region	PP2000	PP2080	% Change
N Namib	8 148 187	7 966 627	-2.2
Central Namib	3 634 438	3 021 807	-16.9
S Namib	3 801 814	3 261 031	-14.2
Nama	2 187 823	1 799 096	-17.8
S Kalahari	82 439	86 176	4.5
N Highlands	6 953 828	7 165 227	3
Central Shrublands	5 031 922	4 908 301	-2.5
Central Kalahari	3 165 280	3 213 166	1.5
N Kalahari	8 112 039	7 552 630	-6.9
Karstveld	3 457 586	3 424 461	-1
W Savanna	2 456 772	2 446 857	-0.4
E Savanna	3 927 390	3 847 292	-2
Total for conservation network	**50 959 518**	**48 692 671**	**-4.4**

Maintaining ecological processes

Ecological processes should be maintained through the following measures:

- Facilitate species movement through building a landscape-level biodiversity corridor network that will allow biodiversity to respond to changing climates. Three large-scale corridors are suggested for Namibia – two already exist to a greater degree (the north-south Namib/Escarpment and east-west Kaokoveld-Caprivi corridors) and one (west-east southern Namib-Kalahari corridor) still needs to be created.
- Promote persistent populations by consolidating areas within the existing conservation network by removing fencing to create larger contiguous management areas that that meet viable animal population size requirements and facilitate species movement in response to seasonal variation.
- Cooperate with neighbouring states when planning and implementing landscape-scale corridors to align conservation management efforts across political boundaries. Biodiversity does not recognise political boundaries.
- In light of the pressures on wetlands in Namibia it is also important that a national wetlands policy and action plan be agreed and implemented that takes full account of wetland catchments that safeguards these essential ecosystems. The Eastern Zambezi-Chobe River and floodplains, the Kwandu-Linyanti system,

the lower Kavango River in Namibia and the Nyae-Nyae Pan system should be considered as potential Ramsar sites.

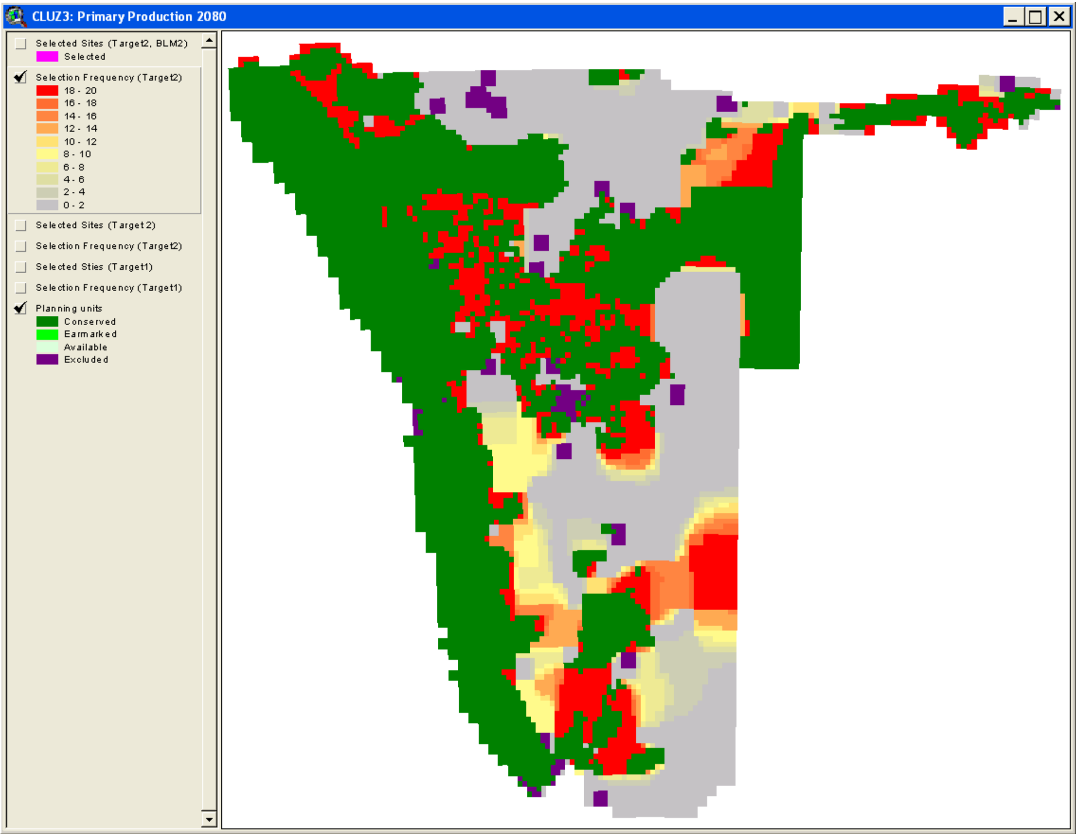


Figure 10.4. Outputs from the MARXAN models showing the selection frequency of sites for 20 model iterations: to represent equal proportion of future PP, with a moderate adjacency requirement

Achieving conservation through voluntary land-use shifts

It is envisaged that the proposed expansion of the conservation network would require further interventions of the nature of those already carried out by the existing CBNRM programme as well as more general interventions aimed at incentivising the move towards wildlife-based enterprises.

Achieving increased conservation through voluntary actions by landowners can be stimulated by active promotion of nature based tourism, as well as general preparation for major shift in land use to wildlife-based enterprises. The three most lucrative components of wildlife-based enterprises, namely tourism, trophy hunting and live sale of high value species, can be managed for optimum production by managing populations to produce trophy animals, favouring high value species rather than large numbers of common species, and by promoting landscape and wilderness oriented tourism together with wildlife, in professional ways, focusing on the complete ecosystem and all its components.

Promoting the transformation of land use to wildlife-based industries will require:

- broadening the expertise among land owners, custodians, managers and employees and building their capacity in a competitive service-oriented and global market, particularly in the areas of trophy hunting and tourism;
- land owners and custodians to improve their product and the marketing thereof by forming strategic co-management partnerships with neighbouring land owners and custodians, to be able to offer a diversity of open landscape and wilderness products together with wildlife, linking high profile areas such as key features and national parks into the product;
- better, more accessible and locally relevant information on wildlife management and monitoring techniques, best harvesting practices, etc.; and
- the establishment of a Wildlife Management Association in Namibia, representing all sectors, as a membership organization, to represent the interests of all wildlife producers, be they for game meat production or non-use photo tourism.

Nevertheless, it must be borne in mind that tourism can only be promoted up to a point, as there will be carrying capacity constraints, beyond which there will be negative impacts on biodiversity and/or its tourism value. These constraints may be exacerbated by water shortages.

10.2.2 Promotion of activities that reduce bush encroachment

Bush encroachment causes a major loss of productivity of rangeland and has affected large areas in Namibia. The losses to Namibia's cattle industry are estimated to be in the region of N$1.2 billion per annum at today's beef prices (de Klerk, pers. comm.) Various methods of bush clearing and management are used, but one of the major problems for farmers is the cost. It is therefore necessary to recover some of the costs through commercial sale of bush products, as follows:

- Charcoal is marketed as an environmentally friendly product made from invader bush. The charcoal industry has grown considerably in recent years and currently 200-300 farmers are engaged in charcoal production, producing 50 000 – 90 000 tonnes per year (NAU 2010). The bush harvesting process takes relatively thicker stems and branches and leaves behind smaller bushes which can grow to marketable size, so this is more of a harvest than a debushing activity, and is very effective at providing an economic incentive to thin bush so that productivity of rangeland improves.
- Wood sold for fuel is another alternative for farmers who want to clear bush on a large scale. Fuel wood is marketed locally as well as exported to South Africa and the EU. Although this can help to reduce bush encroachment, non-encroacher species such as camelthorn *Acacia erioloba* are also targeted, which is not desirable on a large scale.

- Extruded wood logs ('Bushbloks') are manufactured in a small factory in Otjiwarongo. The main objective is to thin encroacher bush to enhance the habitat for cheetah. The enterprise recognises that the market for Bushbloks is quite small but is adequate for its purposes.
- Poles and droppers have a very small market. Some farmers, in the process of charcoal harvesting, select long thin poles (especially from mopane) and treat them against insect attack, and sell to small, local markets.

At present there is a pilot project to test the viability of generating electricity from encroacher bush using a wood gasification process. The high capital cost of the apparatus is the main obstacle to widespread application of this potentially profitable approach. A proposed cement factory close to Otavi intends to clear bush for use as a fuel for firing its kilns. Pelletizing of wood for use as a co-combustion fuel for electricity generation has been proposed but not fully tested. Other uses such as wood chip briquettes, wood-cement boards, chipboard have been tried but not survived.

10.2.3 Ex-situ conservation

Preserving species in artificial environments (e.g. zoos) should be regarded as a last resort. However, in some cases, it may be appropriate to develop programmes where species' survival is assisted because of extreme pressure in their natural habitat. A good example is cheetah, where the Cheetah Conservation Foundation (CCF) has provided land and facilities where 'problem' or 'rescued' cheetah are housed, thus reducing the number that are killed by farmers. Similar projects focus on leopard and other predators that come into conflict with farmers. In most cases, these animals are not released back into the wild, but there have been examples where suitable land has been found to relocate cheetah and thus start or boost a new/small population (e.g. NamibRand reserve). Also, it may in future be possible to boost cheetah populations in bush encroached areas, after a bush thinning programme has been successfully completed and the habitat becomes more conducive for their survival. However, most of the captive animals are used instead for education or tourism purposes. In other countries, breeding programmes for highly endangered species have been set up (e.g. wild dog in South Africa), with the intention of repopulating areas where they previously occurred.

The collection of seeds of indigenous plants is ongoing in Namibia through the Kew Garden's Millennium Seed Bank Project. The project started in 1995 and Namibia is one of nine participating African nations (www.nbri.org.na). The project aims to carry out research to improve all aspects of seed conservation and facilitate access to information and transfer of best practice in seed banking to all project partners. Also, it increases public awareness of the need for plant conservation and make seeds available for conservation in the wild and for research.

10.2.4 Monitoring

A properly-designed monitoring program will allow biodiversity trends and status within the protected area network to be assessed. The rational for monitoring is that it allows a clear trend to be established which can be correlated with climate data to give an understanding of the impacts of climate change. An additional rationale is the fact a clear monitoring program engages key stakeholders and provides a platform for consultative decision making, agency collaboration and public engagement and communication on the issue of climate change.

Key requirements of a monitoring program would be to establish an inventory of flora and fauna within the protected are network. This would be a collaborative process using earth observation technology and a system of ground based surveys and dedicated monitoring and analysis team. This considered, a list of monitoring indicators is proposed which would form the framework within which a monitoring program should be developed. These are listed in Table 10.6

TABLE 10.6. SUGGESTED MONITORING INDICATORS FOR BIODIVERSITY IMPACTS OF CLIMATE CHANGE

Indicator	Description	Target
PRIMARY INDICATORS		
Occurrences of human wildlife conflict, and their management	Number of wildlife incidents reported; Presence of human wildlife conflict management programmes, i.e. compensation programs, prevention programs.	Incidents do not increase disproportionately (regarding increased wildlife densities); Human-wildlife conflict policy implemented, prevention and compensation plans in place.
Establishment and expansion of wildlife movement corridors	Three main corridors (linking protected areas) were identified to allow for wildlife movements in response to climate change impacts. These should be expanded through public-private conservation partnerships and the expansion of the communal conservancy network.	Increased size (ha) of protected areas in the north-east, north-west and south-west corridors; Increased number of public private partnerships in conservation.
Changes in distribution and abundance of endemic species	The endemic belt in Namibia extends mainly from the 50mm to 350mm mean annual rainfall isohyet. Endemic species populations numbers and distribution will change with changes in the rainfall regime; Coastal fog dependent endemic species are expected to react to changes in the occurrence of fog. The impact of climate change on fog is currently not known.	Populations are allowed to move in response to climate change, and numbers do not decline; Populations of fog dependent species do not decline.

Indicator	Description	Target
SECONDARY INDICATORS		
Change in the distribution, abundance and impact of flagship species	Habitat modification and destruction by elephant may increase with decreased forage productivity; White rhino distribution is expected to retreat from the west and south, and expand to north-eastern Namibia; Hartmann's Mountain Zebra are nomadic and if allowed to move across a greater area in response to climate change, the population is expected to continue to increase in number.	Loss of biodiversity and extent of elephant damage to habitats should not increase; White rhino populations do not decrease, but changes in distribution are acceptable; Growing population number trends will continue.
Change in the distribution and abundance of wetland species	Direr conditions lead to increased abstraction of water from ephemeral river systems, resulting in mortalities in large tree species such as *Faidherbia albida;* Population size in the inland ephemeral wetlands of wetland bird species is expected to decrease with climate change. Species such as Slaty Egret, African Marsh Harrier, Wattled Crane, Chestnut-Banded Plover and Lesser Flamingo should be monitored.	Water tables should be maintained to prevent mortalities in large tree species in ephemeral rivers; Presence and abundance of selected wetland bird species should not decrease in inland wetlands.
Change in the distribution and abundance of predator and scavenger species	No major changes expected, although conflict with farming communities should be monitored as a measure of stress on their ecosystem and resource availability.	Conflict between farmers and predators / scavengers does not increase disproportionately to population size.
Change in distribution and abundance of woodland species	Tsessebe, Roan and Sable Antelope are expected to be sensitive to climate change impacts. Their distribution and numbers should be monitored.	Numbers remain stable or increase; there are no population crashes around the 400mm rainfall isohyet.
Change in the distribution and abundance of common savanna plains species	Gemsbok and springbok as hyper-adapted species. Population size and mortalities along fences should be monitored; Burchell's Zebra, Blue Wildebeest and red hartebeest represent common plains species predicted to decrease in population size with climate change. Population size within protected areas should be monitored.	Gemsbok and springbok population numbers do not decrease, and there are not increased mortalities along fence lines; Population size does not decrease.

10.3 Specific options for reducing indirect impacts on biodiversity

The measures described above will only be effective if they are undertaken hand-in-hand with measures that will reduce the pressures on biodiversity that arise as a result of impacts on the agricultural sector. Options are listed and discussed in Table 10.7.

Table 10.7. Options for reducing impacts on agriculture and livelihoods

Climate change impact	Adaptation
Shortages of water (due to decreased supply and increased demand) leading to conflicts, reduced water quality etc	• Improve water supply: o Artificial recharge of underground aquifers (limited viability) o Desalination (coast) o Catchment management e.g. through incentive measures such as PES o Interbasin transfers o Appropriate water harvesting systems (e.g. jojo tanks, dew harvesting) • Reduce demand & use: o Water demand management o More economically efficient water allocation o Water saving technologies o Drought resistant crops o Indigenous species for farming
Reduced productivity leads to increased poverty putting pressure on natural resources	• Diversify livelihoods, • Build capacity and skills to adapt
Competition for land (competing with conservation needs) and pressure to hand protected areas over to farmers	• Enable community involvement in tourism in parks, integrate parks into local economies
Increased pestilence and disease, endemic species outbreaks	• Promote prevention measures; • Improved public health infrastructure • Maintain healthy ecosystems • Early warning systems, monitoring systems
Unpredictability	• Improve meteorological and climatic forecasts as early warning system and fire warning system • Adoption of adaptive management strategies • Adopt a mix of long and short term strategies
Shortage of natural resources due to reduced supply and increased demand	• Support efforts to manage natural resources • Product diversification

10.3.1 Increase water supply

One of the most direct needs for adaptation as a result of climate change will be within the water sector. Adaptation would be across a wide scale for example the adoption at a national level of Integrated Water Resource Management that encapsulates suitable context specific approaches. This is particularly relevant for Namibia, where cross boundary hydrological resources are shared and therefore there is a common interest to adapt adequately and therefore utilize water resources in the most efficient way. Integrated basin management should be encouraged in Namibia because it links water and wetland resources within the basin, with their users, economic value and conservation (Bethune *et al.* 2007). Obtaining a big picture understanding of water and wetlands helps to predict changes and threats, and thus improve management.

Large scale adaptation strategies with relevance to biodiversity conservation and protected areas include addressing supply through transfers between water basins, rehabilitating water basins through revegetation and riverine protection (Clements 2009). Interbasin transfers have previously been mooted (e.g. Congo River) and in some cases (e.g. Okavango ENWC) intensively studied. The latter is not so much an interbasin transfer, but rather bringing water from the Okavango, adding it to the water abstracted from the Karst aquifer, and gravitating it to central Namibia. None of the current proposals seem viable at present and are unlikely to be supported in the short term.

Other means of addressing water supply include artificial recharge of aquifers and desalination. Artificial recharge of underground aquifers has limited viability, but is already practiced as part of the Omdel scheme in the lower Omaruru River. Smaller schemes have existed for years on farms where 'silt dams' hold water in the sand rather than allowing it to evaporate as rapidly as from conventional surface dams. Artificial recharge is also under consideration for Windhoek. Key problems are ensuring that the 'injected' water is of a good enough standard so that it does not pollute the aquifer. In most cases, the water from dams (the most likely source of 'injected' water) is of low quality and needs to be treated to make it suitable for aquifer recharge. This adds considerably to the expense of such schemes.

Desalination of sea or brackish water has historically been prohibitively expensive, but technology is improving and desalination plants are becoming both economically viable and commonplace in some areas, such as South Africa. There is currently an industrial size desalination plant under construction near Wlotskasbaken to supply Areva mine with potable water, and a number of smaller units have been established elsewhere in Namibia. Because of the central Namib 'Uranium Rush', NamWater is considering constructing a desalination plant at Mile 6, north of Swakopmund. These plants are viable where there is industrial demand that can justify the very high capital costs, but they are unlikely to supply much more than specific coastal areas because of the high costs of pumping water up-hill to the interior of the country.

Alternative water harvesting systems could include fog and dew harvesting, but the use of these technologies are currently limited to experimental projects. It seems unlikely that water harvesting will have any major impact on water supply in future decades.

10.3.2 Reduce water demand

Reducing water demand will also be essential. In urban areas, water demand management, effluent recycling and resource recovery projects improve water use efficiency, are good for economic development and adapting to climate change because they reduce the need to exploit other water resources. More economically efficient water allocation and appropriate pricing has been identified as a key factor in contributing to unsustainable water use (Dewdney 1996). Water pricing must reflect the full cost of water provision and opportunity costs. Implementation of block tariff charges (in urban areas) helps subsidize the poor and achieve overall cost recovery. In rural areas, communities generally pay the full cost of an installation through the contributions of their labour and the price they pay for water to the Water Point Committees (WPCs) once the installation is operational. However, managing debt and recovering payments remains a major obstacle.

Drought resistant crops are planted in the northern communal areas, but various government initiated projects still promote water inefficient crops (e.g. maize). More emphasis on the propagation of drought resistant crops is needed. Indigenous species for farming could also improve the ability of farmers to maintain livestock productivity. Promising options include drought adapted Tsonga cattle and various sheep and goat breeds. Perhaps the best option is mixed livestock and game farming, which will enable optimal utilization of available habitat and scarce water resources.

Water saving technologies are inadequately used in Namibia, and include low flow showers, toilet cistern modifications, etc. Some demonstration projects promoting water saving technologies have been implemented in the fishing industry, but much more needs to be done.

In order to address water demand at a household level more emphasis needs to be placed on wide scale investment and uptake of low cost technologies which on aggregate equate to large changes in supply and demand patterns. Leary *et al.* (2007) provide practical solutions for example:

- Household rainwater harvesting;
- Shallow wells for groundwater extraction for irrigation; and
- Water impounding basins to store water.

The local options offer opportunities for small scale community adaptation projects which can be run and managed by local water associations and promote community empowerment.

10.3.3 Reduce unpredictability in agricultural systems

One of the significant aspects associated with climate change adaptation, when considering biodiversity conservation in Namibia, needs to be on reducing the impacts of unpredictable agricultural production. Smallholder farming is one of the main sources of livelihood for most of Namibia’s rural population (Newsham & Thomas 2009).

The worst impacts of climate change will be felt by the most geographically and economically vulnerable regions. The climate scenarios make it difficult to reliably identify the correct adaptation options and their associated costs. In Namibia where there is a higher certainty around the longer term predictions impact–specific measures and longer term investments are required to avoid maladaptation. These longer term investments need to be chosen so as to maximize net social benefits to reduce vulnerability and strengthen capacity. One of the best ways to respond to uncertainty with the future impacts of climate change, especially with regards to agricultural productivity is to emphasise (and equip communities to engage in) activities less susceptible to climate change (Newsham & Thomas 2009)).

Attention needs to be on disseminating education and knowledge on water saving techniques as well as the most durable crops that can sustain food security but also can adapt to changing climate and soil regimes. There is an existing body of knowledge focused on the ‘indigenous land unit system’ (Newsham & Thomas 2009). This body of local specialized knowledge is used by farmers to ‘understand, classify and utilize’ the natural environment for agricultural purposes (Verlinden & Dayot 2000). This knowledge needs to be documented to give a range of stakeholders a wider understanding of agricultural production systems, as a way of appropriately planning for shortfalls, crop failures and periods of low harvest in line with climate change predictions.

Adaptation policy in Namibia needs to capitalise on existing adaptive capacity in terms of exchanges of ‘agro-ecological’ knowledge (Newsham & Thomas 2009). Newsham & Thomas (2009) found there were instances of ‘knowledge co-operation’ between existing local knowledge and agricultural extension policy. However this needs to be systemised to ensure documented knowledge transfer and capitalising on the derived benefits ‘knowledge co-production’ can have in adapting to climate change.

10.3.4 Diversify livelihoods and build capacity

With conventional agriculture likely to decline and rural people less able to rely on traditional livelihood options, there will be ever greater pressure on various natural resources. The impacts of reduced agricultural productivity can be reduced to some extent by strategies such as diversified livelihoods, shifting to lower input livestock systems, shifting to wildlife and tourism; common property/group tenure rangeland management; and adding value to natural resource products.

It has widely accepted that livelihoods diversification is a long term adaptation strategy that reduces vulnerability to climate change. This strategy is already inherent among poorer households in Namibia as a means of coping with current levels of climate variability. Ideally, promotion of further diversification should encourage value added and higher income activities, preferably also involving low carbon development (Newsham & Thomas 2009).

In order to diversify their livelihoods, farmers will need to shift to lower input livestock systems, and increasingly rely on the comparative advantages offered by wildlife and tourism. For this to succeed in communal areas, land tenure issues need to be resolved so that there are incentives for communities to properly manage their rangeland and livestock/wildlife resources.

Shifts to wildlife farming will require parks to supply stock for reintroductions to other areas. Whilst this will place pressure on parks, it will require MET to reconsider the role of parks. These areas will need to be resource banks rather than refuges. The best way for this to happen, is linking parks with conservancies (both communal and commercial), so that wildlife can move freely and thrive even under climate change. In this way, the “whole will be far greater than the sum of the parts”. All of this will require building capacity and skills to adapt to changing land uses.

10.3.5 Reduce park-neighbour conflicts

The Namibian national park system, with its extensive land coverage has great potential for joint larger scale protected area networks, which would create more cohesive units and create a more robust buffer for biodiversity conservation. The Human Wildlife Conflict Management (HWCM) Policy and the Policy on Parks, Neighbours and Resident People have helped provide a legal framework to ameliorate conflicts. However to ensure the policy’s are effective in aiding biodiversity conservation, which will be under increased pressure as a result of climate change, systemic capacity and increased public and private community partnerships needs to be forged.

Rather than turn parks over to grazing for livestock (which goes against the principles of capitalizing on comparative advantages), government should enable community involvement in tourism in parks, and integrate parks into local economies.

10.3.6 Improve management of natural resources

Attention should be focused on Community Based Natural Resource Management (CBNRM) which engages communities and nests management within a local context. As Mbaiwa (2004) found in the Okavango in Botswana, CBNRM programs allowed local communities to provide leadership in natural resource management. However in the context of adaptation polices CBNRM was to be cognisant of weaknesses in existing programs for example a lack of entrepreneurship, managerial skills and poor benefit sharing (Mbaiwa 2004).

10.3.7 Address health impacts

The implications of climate change are wide ranging and will affect human health in terms of water, food and air. In addition certain climatic events will have fundamental influences on exposure risks to new diseases those that have shifted in their range or enlarged in their area of impact. Due to climatic uncertainties, it is difficult to assert the impact climate change will have on health. However adaptation to some degree will be required especially when considering vector-borne diseases that already have an impact in Namibia, like malaria and diarrhoea.

One of the key ways of addressing health impacts is for public health infrastructure to be improved, as the IPCC (2001) identified this as one of the 'most important, cost effective and urgently needed adaptation strategies'. Organizational capacity needs to be invested in prevention and control measures for disease exposure and transmission, as important adaptation strategies in the health sector under modeled climate scenarios (McMichael *et al.* 2003). This needs to be done in line with a context specific assessment of local resource use so some measure of understanding and assessment can be gauged for the extra stress and risk to biodiversity, through traditional medicinal demand.

An important way to reduce the threats of pestilence and disease is to maintain biodiversity, avoid monoculture and especially to protect predators that can keep pests in check. Early warning systems and monitoring systems should also be in place.

10.4 Is Adaptation worthwhile? An assessment of costs and benefits

10.4.1 Introduction

It is well established globally that mitigating climate change alone will not be sufficient and that adaptation will have to be employed. Funding will be required to implement necessary adaptation to climate change. Any investment needs to consider a 'climate mark-up' which should be pitched against investment levels that reflect current trends, which could be analyzed as being insufficient to remove high levels of climate vulnerability (Parry *et al.* 2009).

Economics can provide valuable guidance on consequences by clarifying policy towards viewpoints of aggregated consequences (Dietz *et al.* 2008). However, this can be challenging, as futures markets only cover a few decades and are not applicable for the time period needed for climate change, which is many decades and centuries (Dietz *et al.* 2008). A major ethical issue in deciding on adaptation options is the fact that because these markets cannot directly reveal appropriate investment needs in the interest of future generations, those who will be most profoundly affected by climate change, especially highly vulnerable rural agriculturalists, are not adequately addressed. For an appropriate economic analysis of adaptation options a pure time discount rate needs to be decided upon as well as the marginal utility of an adaptation optional investment, both of which require an ethically sound approach.

There are very few country-level studies into adaptation costs, and currently most research has focused on global estimates of adaptation costs (Table 10.8). One of the primary reasons for evaluating the costs of adaptation is an attempt to determine the optimal combination and level of adaptation and mitigation (Parry *et al.* 2009).

The wide ranging changes that will occur as predicted by climate models will result in far-reaching impacts for multiple sectors. These will have direct economic consequences, as summarized in Table 10.9, as well as potential non-economic consequences.

In the case of Namibia, the high levels of climate variability and current lack of reliable data result in a very restricted predictive capacity of the climate models (Newsham & Thomas 2009). This creates difficulties in attempting economic analysis as any effort to downscale costs can amplify errors in the lower resolution near-term models, causing an inaccurate cost benefit analysis of climate change adaptation required for the protected area network. The most certain climate predictions occur from 2080 onwards and therefore do not allow enough confidence to carry out economic analysis for adaptation in the near term periods. In the most recent national assessment of climate variability Dirkx *et al.* (2008) concluded that it remained unclear exactly *what* needed to be adapted to in Namibia. The high level of uncertainty is not conducive to rigorous economic analysis of adaptation options. Thus the analysis presented here is a rough assessment only.

Table 10.8. UNFCCC estimate of additional annual investment and financial flow needed by 2030 to cover adaptation costs (adapted from Parry *et al.* 2009)

	Global Cost	Cost for developing countries (US$billion p.a)	Reason for adaptation costs
Agriculture	14	7	Extra capital investment at farm level, need for better extension services at country level & additional global research
Water	11	9	Additional water demand & changes on supply side
Human health	5	5	Extra prevention costs of 3 key health issues: malnutrition, malaria & diarrhea

Table 10.9. Potential consequences of climate change on key sectors in the absence of adaptation (Adapted from Parry *et al.* 2009)

Activity	*Potential economic consequences*
Domestic/municipal	Cost of altered health & dealing with droughts
Agricultural	Cost of change in productivity
Sanitation & effluent removal	Cost of impact on in stream ecosystems & pollution incidents
Flood management	Change in economic value of flood damage
Water level & soil water management	Water shortages
Ecosystem services	Replacement of natural services

10.4.2 Economic assessment of direct interventions

In this study, we considered the potential costs of the interventions required to combat the direct impacts of climate change. Of course, these interventions also help to address some of the pressures on biodiversity that arise indirectly. However, we have not considered the costs of interventions specifically addressing other sectors such as water.

The changes expected by 2080 in direct economic contribution resulting from climate change will take place over seventy years and will be mitigated to some extent by autonomous adaptation. Thus, for example, fenced commercial ranching will tend to be replaced by more extensive low input systems, and cattle over much of the drier savanna areas will tend to be replaced by small stock. These changes will happen gradually without any intervention. The losses in tourism demand will tend to be offset by natural growth in overall international demand for tourism and the potential for expansion of tourism in underutilised areas, particularly in state protected areas and communal land. Losses in grazing wildlife numbers should be offset to some extent by increases in wildlife on under-stocked land as well as the taking up of unused capacity for wildlife use in state protected areas and communal lands. Wild plant use is generally well under the national potential for use of these resources, and it is generally likely to increase as other livelihood options through agriculture area curtailed.

Given autonomous adaptation, losses in production will tend to be reflected in loss of growth that would take place in the absence of climate change. Also given that these losses will be most acutely felt in the agricultural sector, active interventions should include shifts toward the more resilient land and natural resource uses, as well as efforts to make land uses less rigid and more able to change and adapt. Recommended interventions thus involve more spatial mobility and focus on improved management of natural resources, and rangelands. They do not involve extending the state protected area system, but rather extending the development of community and private conservation areas within the conservation network, particularly in those areas targeted as key in relation to losses in biodiversity.

These interventions would largely amount to additional, focussed CBNRM interventions in Namibia that build on the existing CBNRM programme. The related interventions, such as promotion of wildlife tourism and veld management activities can be seen as integral to these interventions.

For the economic assessment, CBNRM interventions in five specific hotspot areas, two on communal land, and three on freehold land were examined. The target interventions would focus on some 36 000 km^2. These were treated as development projects to encourage and facilitate appropriate land use and management change, to be carried out as part of the national CBNRM programme. Average capital and recurrent intervention costs and likely direct economic benefits were calculated using data from the CBNRM programme (NACSO 2004, 2006, 2008, Barnes 2008, Barnes *et al.* 2002). Downward adjustments to cost figures amounting to 33% were made, with consideration of the sunk costs in the CBNRM programme. Costs and benefits streams were adjusted for differences between the target areas with respect to the degree of intervention considered necessary. Benefits streams were adjusted down by between 10% and 20% to account for predicted lower growth in tourism and lower rangeland carrying capacities. Flows of project intervention costs, and likely flows of economic benefits resulting, were predicted for the five target areas, to derive crude cost-benefit assessments over 30 years.

Table 10.10 shows some base case results of this assessment, which must be seen as preliminary. It provides an estimate of the total funds (in 2009 present value terms) that would be required for the first five years and 30 years for the interventions recommended. The results suggest that an initial five year project would require some N$55 million and that over 30 years of intervention, some N$155 million. Indications are that over 30 years the intervention would be economically efficient, with a base case economic rate of return (ERR) of some 20%. Rates of return would be likely to differ with project area and ERRs between 10% and 30% might be expected.

Table 10.10. Assessment of costs and economic viability for five CBNRM interventions targeting hotspots in mitigation of climate change

Project area	**Extent km^2**	**Project intervention cost**		**Viability**
		5 year PV*	**30 year PV***	**30 year ERR**
Kaudum area	6 000	10 433 800	29 419 100	13%
Kalahari TFP area	6 000	9 485 300	26 744 600	21%
South west escarpment	12 000	18 022 100	50 814 800	27%
Fish River area	7 000	9 959 600	28 081 900	28%
North west area	5 000	7 114 000	20 058 500	18%
Total intervention	**36 000**	55 014 800	155 118 900	**23%**

* The present (2009) value of five and 30 year streams of costs

The results of this analysis suggest that adaptation can be carried out in an economically efficient manner. This is an extremely positive result, in that adaptation simply to offset the potential costs of climate change is unlikely to be economically efficient when there is no added benefit derived from the adaptation measures, especially over the long time periods and given the high levels of uncertainty involved. In the case of the CBNRM activities, the benefits are anticipated to be greater than just the offsetting of potential losses due to climate change.

10.5 Strengthening environmental institutions and policy

10.5.1 The importance of policy response

Adapting requires local solutions, since the direct impacts of climate change are felt locally, and response measures must be tailored to local circumstances (Bruce *et al.* 1996, Burton *et al.* 2006). Thus, adaptation measures must be guided and supported by national policies and strategies, which have relevance and strong support at both grass-roots and political levels.

From a policy perspective, the barriers to adopting a proactive approach in Namibia and elsewhere include:

- Typically short term thinking at local and high political level
- Limited ability to understand 'big picture' concepts, such as the need for catchment approaches for river and wetland management, open ranching systems (whether livestock or game), and the opposite tendency to fragment habitats through fencing and other barriers,
- Resistance by government to forming genuine partnerships with landowners (e.g. park neighbours) and Civil Society, who could help limit vulnerability
- Poor governance – safeguards (e.g. building setback lines) are often ignored when developers pressure local authorities to allow sea or river front development. Also, safeguard tools (such as SEA and EIA) are sometimes circumvented for short term political expediency (e.g. Ramatex).
- Inability or unwillingness to make unpopular political decisions, such as
  - prescribing where people may or may not settle (e.g. in oshanas),
  - limiting stocking rates (and forcing/facilitating offtake) during dry cycle periods,
  - setting conservative quotas for commercial fisheries,
  - committing to required, initial expenses at strategic level (e.g. SEAs and EIAs) and implementation level (e.g. placing adequate bridges under roads, installing well designed and built sewerage systems, etc.),
  - preventing the establishment of artificial water points in certain grazing areas (or avoiding closing them when grazing is depleted).

Thus, Namibia's ability to adapt requires appropriate policies and laws, functioning institutions, consistency in decision making, educated and competent citizens, access to technology and, of course, a reasonable level of wealth. In the future as in the past, the success of adaptation to climate will require choosing the right development options, so that those who are vulnerable (inevitably the poor) are not exposed to greater climate risk, and so that environmental integrity is maintained.

10.5.2 The Policy Context

International commitments to natural resource management

The United Nations Convention to Combat Desertification (UNCCD), the Convention on Biodiversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC) were established during the early 1990s. Namibia became a signatory to each of these Conventions in 1997.

The Millennium Development Goals

The eight Millennium Development Goals (NPC 2004) are to:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote greater equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

The government is implementing the Millennium Declaration and monitoring the MDGs within the context of national and sectoral development frameworks.

The Namibian Constitution

Since Independence, the Namibian government has adopted a number of policies that promote environmental health and sustainable development. Most of these have their roots in the following two clauses of the Namibian Constitution:

Article 91(c), which defines the functions of the Ombudsman to include "… the duty to investigate complaints concerning the over utilisation of living natural resources, the irrational exploitation of non-renewable resources, the degradation and destruction of ecosystems and failure to protect the beauty and character of Namibia."

Article 95(l), which commits the State to "actively promote and maintain the welfare of the people by adopting … policies aimed at…..the maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and the utilisation of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future.

Vision 2030

Namibia's Vision 2030, which was formulated in 2001/2002, aims to guide the country's five-year development plans from NDP 2 through to NDP 7 and, at the same time, provide direction to government ministries, the private sector, NGOs and local authorities. For the Natural Resource Sector, Namibia's Vision is defined as:

" The nation shall develop its natural capital for the benefit of its social, economic and ecological well-being by adopting strategies that:

- Promote the sustainable, equitable and efficient use of natural resources;
- Maximize Namibia's comparative advantages;
- Reduce all inappropriate resource use practices.

However, natural resources alone cannot sustain Namibia's long-term development, and the nation must diversify its economy and livelihood strategies".

National Development Plan 3

NDP3 states that most sectors did not meet NDP2 targets "owing to changeable climate conditions and unfavourable exchange rates" (GRN 2008). The Plan takes a thematic approach, and sets goals for each Key Result Area. This moves away from the Ministry-by-Ministry approach used in previous Plans, with the aim of bringing integration to the sectors.

The Poverty Reduction Strategy and Action Plan

Central to all three environmental issues of desertification, climate change and biodiversity loss is poverty - both as a cause of these issues and as a consequence of their manifestation. Consequently, measures aimed at diversifying/improving rural livelihoods should help to alleviate all three environmental issues. The Poverty Reduction Strategy focuses on:

- equitable and efficient delivery of public services for the poor (emphasising decentralisation);
- agricultural expansion and strengthening food security; and
- strengthening non-agricultural, informal and self-employment options.

Swapo Political Manifesto (2004)

The ruling party's latest manifesto (produced before the latest national elections in 2004) is committed to peace, unity and sustainable development. In 'Building a socially just society', the Swapo government plans to 'accelerate the acquisition of land to resettle communities and provide them with the necessary productive and environmental management skills.' With respect to Infrastructure, provision of water to the rural population is planned to increase from 75% in 2004, to 85% in 2010, and to 100% in 2030. Expansion of the community-based water management strategy is promised. A new water law (presumably referring to the Water Resources Management Act of 2004) will enable the government to subsidise water to the needy. In line with the decentralization policy, all regional water supply resources will be decentralized by 2010. In 'Building a vibrant economy', it is stated that Namibia's agronomic sub-sector has the brightest prospect to make the most immediate and significant contribution to the country's economic growth and job creation. Irrigation schemes such as Brukkaros and Naute Dam, and large-scale production of cotton in Kavango and Caprivi are planned, and it states that Namibia will become a hub for the textile industry in southern Africa. In the section on tourism, conservancies are predicted to grow considerably, with associated local employment opportunities and joint venture partnerships. Sections on manufacturing, the SME sector, mining, aquaculture and fisheries proclaim great increases in available jobs.

10.5.3 Strengthening institutions and policy

Formal and informal institutions such as government ministries, civil society organizations and community based structures need to be involved in the decision making process regarding adaptation (Parry *et al.*2009). This must occur through a dedicated process of building skills and knowledge sharing between the groups. There needs to be a conducive environment to form networks that can aid government to design and manage budgets and enforce applicable laws regarding biodiversity conservation and protect vulnerable communities. The strengthening of these institutions is essential to support the execution of adaptation measures.

Environmental policies will also need to be strengthened in order to make them more resilient to climate change. Policy weaknesses of the environmental sectors, and recommendations for rectifying these are summarized in Table 10.10.

Table 10.10. Policy weaknesses and recommendations for key sectors (see Appendix I for more detail)

Sector	Key policies	Policy weaknesses	Policy Recommendations
Agriculture	• National Agricultural Policy (1995) – revision started in 2005, still ongoing • National Drought Policy and Strategy (1997) • Green Scheme Policy (2004, revised in 2008) • A National Rangeland Management Policy and Strategy is in compilation, led by the Emerging Commercial Farmers Support Programme in NAU	• Poor implementation of drought policies • Severe funding limitations – especially Green Scheme developments • Human resource shortages – irrigation farming, DEES and DART advisors • Lack of long term adaptation planning – for example stocking rates and carrying capacity	• Revive FIRMs established under Napcod and roll out approach • Involvement of Agra, Meatco and other agricultural enterprises in training, livestock improvement, and rangeland management • Agricultural policy to promote diversification of livelihoods • Revised Green Scheme Policy (2008) to build in local irrigation expertise and ensure doesn't conflict with Agricultural Policy regarding issue of subsidization – MAWF subsidization increases dependence on government and vulnerability • Green Scheme policy revision should be abandoned and the directives in the original Green Scheme Policy (2004) should be re-established Drought Policy is very thorough yet urgently requires an implementation plan • Increase land productivity – analyze impact of subsidization policies • Need for policies to address bush encroachment and to promote sustainable cattle grazing hat encompasses ideals of natural resource management • Improve local level empowerment, strengthen the Emerging Farmers Communal Support Programme with NAU
Water	• Water Supply and Sanitation Policy (WASSP, 1993) • National Water Policy White Paper (2000) • Water Supply and Sanitation Policy (WASSP, 2008 revision) • The Water Resources Management Act (2004, presently being revised)	• Lack of clear guidelines for implementation of the block tariff system	• The recently completed revision of the WASSP (2008) should be compiled in a user-friendly format with clear guidelines, and should be widely distributed to all LAs and MRLGHRD, MAWF and MOH offices • Integration between ministries should be promoted at the technical level

Forestry & wildlife	• Development Forest Policy (2001) • Forest Act (2001) • Wildlife Management, Utilisation and Tourism in Communal Areas Policy (1995) • Amendment to the 1975 Nature Conservation Ordinance (1996) • Promotion of Community-based Tourism Policy (1995)	• DoF nurseries sell exotic and/or unsuitable trees which require supplementary watering. • The Forestry Policy does not address the growing biofuel sector and potential *Jatropha* plantations in north-eastern Namibia • The Forestry Policy directive to plant trees to combat desertification is not appropriate, since many areas of Namibia can only support trees if they are given supplementary water	• DoF should attract investment in cheaper, alternative cooking fuels, since the greatest threat to wood resources comes from wood fuel. Brick-making enterprises are another preferable substitute to wood for construction • DoF extension services and DEES both suffer from inadequate staff. It would appear to be an obvious synergy to join these two units • Need for land use planning and zoning for optimum land uses in different areas • Assess outcome of Strategic Environmental Assessment of the biofuel sector in Namibia for potential policy modifications. Currently WACCP prioritization places domestic requirements top, the ability of the environment to provide the water sustainably should be the most important criterion • The DoF nurseries should only sell indigenous trees
Land	• National Land Policy (1998) • National Resettlement Policy (2001) • Agricultural (Commercial) Land Reform Act (1995) • Communal Land Reform Act (2002) • Draft National Land Tenure Policy (2005, not yet finalized)	• The Land Use and Environmental Boards (LUEBs) and Standing Committees on Land Use Planning (IMSCLUP) have not been established • Resettled farmers receive inadequate support as MAWF provides little extension support to resettlement farms, and MLR has inadequate capacity • The role of civil society in supporting land reform is not mentioned in either the Land or Resettlement Policies. • There are serious delays in the registration of lease agreements for beneficiaries.	• Lack of community user rights over grazing resources – needs to be integrated • The resettlement objective; 'to give target groups an opportunity to produce their own food with a view towards self-sufficiency' is in conflict with the Agriculture Policy and NDP3 • The Resettlement Policy, as it is presently implemented, conflicts with all policy directives to improve sustainable land management • MLR can only successfully implement the resettlement programme with cross-sectoral collaboration with other ministries. However collaboration with and participation of other ministries is poor, which slows down implementation and leaves emerging farmers inadequately supported • The LUEBs at regional and local level, and the IMSCLUP at national level, should be operationalised and resourced as a matter of urgency • Land sector should extend group user rights to grazing resources as its most urgent priority, as inadequate tenure is the biggest obstacle to improved land management on communal land

Environmental Planning	• Environmental Assessment Policy (1995) has recently been enacted as the Environmental Management Act (2007)	• Capacity to guide and review SEAs and EIAs in the DEA is inadequate, and this will require considerable improvement in number of staff and expertise for efficient implementation.	• EIAs need to be thoroughly conducted and reviewed to ensure there are no hidden aspects
Coastal management & fisheries	• Territorial Sea and Exclusive Economic Zone of Namibia Act 3 of 1990 • Marine Resources Act (MRA), 27 of 2000 & inland fisheries by the Inland Fisheries Resources Act 1 of 2003 • Aquaculture Act 18 of 2002	• The existing legal framework has significant gaps from the perspective of integrated coastal management and does not provide an adequate basis for the effective implementation of integrated coastal management. • There is no legislation that has the preservation of the coastal environment as one of its objects.	• The range of legal powers to implement effective coastal management would be greatly enhanced if the Water Resources Management Act, 2004 and the Environmental Investment Fund of Namibia Act, 2001 were brought into force. In addition if the Environmental Management Act of 2007 was implemented, and the draft Pollution Control and Waste Management Bill and the draft Parks and Wildlife Bill were finalized, enacted and implemented • Line ministries and LAs need to significantly improve their governance regarding the allocation of various land and resource-use rights. These include prospecting and mining and urban expansion/development • There needs to be significant improvements in terms of building the capacity of the institutions with major responsibilities for coastal management

11 OPPORTUNITIES FOR GENERATING INCOME THROUGH CARBON PROJECTS

11.1 Introduction

Namibia will need to finance any adaptation measures required as a result of climate change. One of the ways in which finance can potentially be generated is through mechanisms developed for climate change mitigation, in particular, the markets that have developed for projects that reduce carbon emissions or reduce atmospheric carbon as a result of the Kyoto Protocol.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) established a cap-and-trade system for developed countries that ratified the protocol. The system imposes national caps on the greenhouse gas emissions. Each participating country is assigned an emissions target and the corresponding number of allowances – termed Assigned Amount Units (AAUs). Countries must meet their targets by reducing their own emissions and/or trading emissions allowances with countries that have a surplus of allowances; and/or meeting their targets by purchasing carbon credits. The Clean Development Mechanism (CDM) was established under the Kyoto Protocol to assist non-Annex I Parties to the UNFCCC in promoting sustainable development through projects that either reduce emissions or reduce atmospheric carbon, to help Annex I Parties in complying with their emissions reduction commitments. CDM projects generate emissions credits termed Certified Emissions Reductions (CERs), with one CER equating to one tonne of carbon dioxide equivalent, and the CERs can then be bought and traded.

In addition to the compliance market, voluntary carbon markets exist which enable companies, governments, NGOs and individual entities to offset their carbon emissions through the purchase of offsets created through CDM or within the voluntary market, termed Verified or Voluntary Emissions Reductions (VERs). Despite considerably lower trading volumes due to a lack of regulatory stimulus, the voluntary markets allow for innovation due to fewer transaction costs than CDM or other compliance projects. To address quality concerns in the voluntary market a number of voluntary offset standards have been developed to try and ensure quality and additionality of the VERs being generated through the voluntary market.

Projects that qualify for compliance or voluntary credits include technology- or land-based projects. The former are more prevalent in compliance markets because of the difficulties in meeting the stringent requirements in demonstrating the carbon offsets in land-based projects. Compliance project activities implemented in agricultural, forestry and other land use sectors (AFOLU) are limited to narrowly-defined afforestation/reforestation (AR) activities. Nevertheless, the land use sector holds the greatest potential for carbon finance in most African countries.

11.2 Potential for afforestation/reforestation projects

Land-based climate mitigation activities are seen as an essential component of climate change mitigation. These entail both (a) reforestation and agro-forestry activities which can remove carbon dioxide from the atmosphere[14] and (b) the reduction of deforestation and forest degradation to slow down the release of stored carbon. The latter types of project are termed "reduced emissions from deforestation and degradation" (REDD). Both types of interventions often have the added advantage of simultaneously improving biodiversity conservation. Indeed, the recently established Global Conservation Standard (GCS) provides opportunity for the issuance and sale of Conservation Credit Units (CCUs) from REDD projects. If well managed, positive outcomes can be achieved cost-effectively (CCBA 2008). In addition, carbon projects are required to benefit the rural poor and vulnerable communities.

Although Namibia's policies and legislation have not been designed with carbon projects (through restoration or REDD) in mind, the policy environment is conducive to implementing these approaches, since the principles that underlie them are embodied in natural resource policy and legislation (Jones & Barnes 2009). Communities are able to enter into contracts with external agencies and are able to retain the income accruing to them. The community-based wildlife and tourism programme provides incentives for the setting aside of habitat which also contributes to avoided deforestation. These policies generally favour the rural poor.

The potential viability of implementing carbon projects will depend on the degree to which deforestation has occurred (providing potential for restoration), or the degree to which forests that are currently intact can be demonstrated to be under imminent threat of deforestation.

In Namibia, most woody biomass is in the northeastern parts of the country, and much of this coincides with the communal land areas where population densities are high. In these areas, people use woodlands for grazing and firewood harvesting. Some forest clearing occurs, but this tends to be close to villages. Clearing for agriculture is not much of a threat because there is no incentive – the net benefits of agricultural land uses are typically smaller than those from using woodlands themselves. Agriculture thus remains a subsistence activity for maintaining household food security. Woodlands are also regularly burnt for grazing, which reduces woody biomass as well as increasing carbon emissions. Indeed, bush encroachment tends to be more of a problem, which entails increases in biomass. In these areas, some farmers make an attempt to open up the land for grazing, and use the harvested material to make

[14] In the case of CDM projects, only land that has not been forested since January 1990 is eligible for Afforestation/Reforestation projects.

charcoal to make this viable. Furthermore, there is minimal harvesting of timber in Namibia. Thus in general, Namibia's woodlands have not been impacted very much, as there are vast areas that are relatively remote and intact.

Jones & Barnes (2009) conducted a detailed analysis of the potential of introducing REDD projects in Caprivi. This region was selected as the region in which such projects would be potentially most viable, given the natural woody biomass of the area. They found that the rates of deforestation were much lower than those of other parts of the miombo eco-region beyond Namibia, where uses such as charcoal production are prevalent. Household shifting cultivation was limited to specific areas and use of forests for poles and firewood is well within sustainable limits for the whole area although there is some over-exploitation close to settlements. Jones & Barnes' (2009) economic analysis demonstrated that the values associated with conversion of woodland were similar or less than the values derived from the unconverted natural woodland itself. Thus there was little incentive for households to engage in practices resulting in significant deforestation.

Commercial-scale irrigation projects also form a potential threat to forest areas. Several proposals have been tabled in the last few years. However, indications from studies in the north of the country are that such projects are generally not economically viable.

Thus it would be difficult or impossible to demonstrate the level of threat necessary for a REDD project. This is likely to be even more the case in the rest of Namibia. As a result, it has to be concluded that it is unlikely that Namibia would be able to generate significant revenue from AFOLU carbon projects.

11.3 Potential for other Projects

Although opportunities for leveraging carbon finance from AFOLU in Namibia are limited, there are other opportunities that exist through the CDM. In general, emissions-reduction projects in developing countries tend to focus on provision of cleaner energy (e.g. hydro, wind, solar and biomass) and capture and use of greenhouse gases from waste. Namibia may have a particular advantage in the production of solar power. Indeed, with an average daily solar radiation of 6kWh.m^{-2}, Namibia's solar potential is amongst the highest in the world (Oertzen 2008). Given the country's high level of dependence on imported power, this is particularly relevant, and could be considered on a large scale. In addition, there may be good opportunities for investing in the provision of biomass energy in areas where bush encroachment has become a problem. The economic feasibility of these options needs to be explored.

12 CONCLUSIONS AND RECOMMENDATIONS

12.1 BIOPHYSICAL PREDICTIONS

Over the past 200 years, global temperatures have been increasing at an accelerating rate, including in Namibia. Further increases in temperature and associated evapo-transpiration are expected across Namibia, with the maximum increases expected in the central interior. Warming is likely to be less along the coast than the escarpment and inland regions, though the levels of uncertainty are high regarding currents, winds, sea temperatures and fog. Most global circulation models and the median of these models project that Namibia will become drier, rainfall variability is likely to increase and extreme events such as droughts and floods are likely to become more frequent and intense. Soil moisture levels are projected to decline, with the cumulative impacts of higher temperature, lower rainfall, higher run-off, lower humidity, higher evaporation and lower plant cover probably creating a compounding impact on soil moisture and on primary production that is greater than the sum of their individual contributions. There are currently no credible projections of changes to Namibia's coastal fog system, which is known to be vital for most endemic and many other plant and animal species in the Namib Desert.

12.2 EXPECTED DIRECT AND INDIRECT IMPACTS ON BIODIVERSITY

Coastal areas are likely to see increased incidence of flooding and inundation, affecting low-lying urban areas. Marine species most sensitive to climate change will be those that have been heavily exploited. The wetland species associated with the large river systems in the north of Namibia are expected to prosper, while the conditions for wetland species at other wetlands in Namibia, both perennial and ephemeral, are likely to deteriorate. Of particular concern is the situation of the Cuvelai and Etosha Pan which is essential to the survival of flamingos in southern Africa.

Terrestrial areas that are particularly vulnerable to climate change include the western escarpment (which separates the arid desert from the semi-arid savannas), and the southwestern Succulent Karoo – both important centres of endemism. The latter is considered to be one of the world's 25 top 'global biodiversity hotspots' and is likely to suffer considerable numbers of local extinctions by 2050. Namibia's vegetation is likely to shift in spatial dominance from Grassy Savanna to Desert and Arid Shrubland by 2080. The south and south west parts of the country are predicted to see the greatest increase in total plant species numbers as well as the lowest proportion of species loss, whereas much greater losses are expected to be experienced in the central, northern and eastern areas. Some 7% of plant species have been estimated to shift their distribution range out of Namibia entirely with 52% of species showing range contractions and 41% showing range expansions.

In terms of relative abundance based on predicted range and carrying capacity changes resulting from projected climate change impacts, wildlife grazers are expected to decline on average by about 13% by 2050 and about 24% by 2080. However the plains game of Namibia can be classed as largely climate-tolerant, with small expansions of range in some species towards the north-east in response to an expected shift of the savanna biome, and small declines in the ranges of some species in the extreme west and south as the hyper arid Namib expands. The woodland ungulates are more sensitive to climate change and climatic variability than the plains species. This is exacerbated by the natural distribution of these species in Namibia being on the drier edges of their ranges where they are particularly vulnerable. A retreat in natural ranges to the north-east should be expected. Predators and scavengers are largely climate-tolerant. If their food source is secure their distribution and abundance will be little affected.

Namibia's farming systems are on the arid margins of viability. The impacts of projected climate change on these production systems are expected to be severe. It is expected that the decline or in some cases failure, of traditional and conventional forms of land use in Namibia's rural areas will have a greater (though indirect) impact on biodiversity than the direct impacts of climate change. This is because people will be forced to use wildlife and other natural resources much more in the future than they do today, in order to survive.

There is thus an urgent need to strategically rethink the adaptive responses of both production and conservation planning in this country over the next few decades.

12.3 Overall recommendations for adapting to climate change

Adapting to climate change requires local solutions that are guided and supported by national policies and strategies, which have relevance and strong support at both grass-roots, political and technical levels.

From a policy perspective, Namibia must overcome the following core strategic constraints:

- Short term prioritization (thinking) at local and high political levels;
- Limited ability to understand 'big picture' concepts, such as the need for catchment approaches for river and wetland management, open ranching systems (whether livestock or game), as opposed to the current inappropriate tendency to fragment habitats through fencing and other barriers;
- Resistance by some sectors of government to forming genuine partnerships with landowners (e.g. park neighbours) and Civil Society, who could help limit vulnerability;

- Poor governance – safeguard tools (such as SEA and EIA) are often ignored or circumvented for short term political expediency; and
- Inability or unwillingness to make unpopular political decisions, such as:
  - prescribing where people may or may not settle (e.g. in oshanas prone to flooding);
  - limiting stocking rates and forcing/facilitating offtakes;
  - setting conservative quotas for commercial fisheries;
  - committing to required, initial expenses at strategic level (e.g. SEAs and EIAs) and implementation level, (this point is not clear); and
  - preventing the establishment of artificial water points in certain grazing areas (or avoiding closing them when grazing is depleted).

Adapting to climate change also requires a strategic rethink of Namibia's approach to sustainable socio-economic development. It is important to note that Namibia already has to deal with severe environmental conditions of poor soils, low and highly variable rainfall, high temperatures, high rates of evaporation and meagre amounts of fresh water. Addressing the challenges of climate change through appropriate adaptation will automatically improve current management practices, enhance sustainability and promote socio-economic development. The converse is also true – that is, better management of the current situation is a pre-adaptation for coping with climate change. Many of the elements required for both improved current management and climate change adaptation are already contained in Namibia's Vision 2030, but have not been put into full effect. The first is to recognise Namibia's strategic comparative and competitive advantages. The second is to strengthen the policy environment to create incentives for the growth of businesses and enterprises around these. The third is the create and nurture strong and full partnerships between government and civil society (business sector, community sector, NGOs and academic institution) with none curtailing the other, with minimal bureaucracy, with maximum collaboration and working to optimize outcomes. And the fourth is to work to identify key bottlenecks and to remove these, so that sustainable socio-economic development is effectively unleashed.

Thus, Namibia's ability to adapt requires appropriate policies and laws, functioning institutions and partnerships, consistency in decision making, educated and competent citizens, access to technology and the appropriate allocation of resources, all of which combined with ensure wealth creation. In the future as in the past, the success of adaptation to climate will require choosing the right development options, so that those who are vulnerable (inevitably the poor) are not exposed to greater climate risk, and so that environmental integrity is maintained.

12.4 Managing the direct impacts of climate change on wildlife and protected areas

In terms of wildlife, there are four possible responses by species to climate change effects. They may:

- be climate tolerant, and show little change to changing climatic conditions;
- expand into new areas as they declines in parts of their existing areas;
- move to totally new areas; or
- be intolerant to climate change and unable to expand or move to and survive in new areas and therefore become extinct in the wild.

The management actions for each of the above biodiversity responses to climate change could be:

- do nothing – the species will look after themselves;
- reconfigure landscapes to facilitate expansion and survival in changing distributions;
- translocate species to new appropriate habitats and manage to ensure their survival; and
- apply ex-situ conservation.

Reconfiguring landscapes and increasing size and connectivity of the conservation network is recommended as the best way to enable wildlife to adapt to climate change. Namibia's conservation network covers 45% of the country or approximately 37 million ha. Privately- and communally-owned conservancies together comprise nearly 60% of the conservation network, though they cannot be assumed to be as efficient as state protected areas in their conservation outcome. Thus it is important to consider both the core conservation area (comprising state protected areas) as well as the important role played by the surrounding lands under wildlife uses.

As a proportion of the country, Namibia probably has one of the largest conservation networks of any country globally. Only 2% of biodiversity features targeted are not represented within the conservation network at all, and a total of 5% fall short of their target. However, given the expected shifts in productivity, maintaining the current populations of the conservation network will require its being expanded by some 35-43%.

The following conservation measures are recommended:

- Addressing gaps in the conservation network by:
    - Expansion and consolidation of conservation areas particularly in the north; and
    - Creation of conservation areas particularly in the SE Kalahari, Nama Karoo and eastern Orange River valley regions.

- Promote persistent populations by removing fencing to create larger contiguous management areas that meet viable animal population size requirements and facilitate species movement in response to seasonal variation;
- Conservation efforts for woodland ungulate species which will no longer prosper in Etosha should be focussed on the Khaudum, BwaBwata and Mudumu Parks;
- Facilitate species movement through building a landscape-level biodiversity corridor network that will allow biodiversity to respond to changing climates. Consolidating the existing conservation network into 3 major bioregional corridors would contribute significantly to the maintenance of macro-ecological climatic gradient corridors. These corridors are the:
    - North-south escarpment/Namib corridor (existing);
    - West-east Kaokoveld-Caprivi corridor (existing); and
    - West-east southern Namib-Kalahari corridor (not existing)
- Cooperate with neighbouring states when planning and implementing landscape-scale corridors to align conservation management efforts across political boundaries;
- Adopt integrated river basin management and develop a national policy and action plan that safeguards wetland ecosystems. The Eastern Zambezi-Chobe River and floodplains, the Kwandu-Linyanti system, the lower Kavango River in Namibia and the Nyae-Nyae Pan system should be considered as potential Ramsar sites; and
- Maintain an ecosystem approach to fisheries management.

In terrestrial landscapes, achieving increased conservation through voluntary actions by landowners can be stimulated by active promotion of nature based tourism, as well as general preparation for major shift in landuse to wildlife tourism. Nevertheless, tourism can only be promoted up to a point, as there will be carrying capacity constraints, beyond which there will be negative impacts on biodiversity and/or its tourism value. These constraints may be exacerbated by water shortages.

12.5 Managing the indirect impacts of climate change on wildlife and protected areas

As noted earlier, the failure of other sectors may be a greater threat to wildlife and protected areas than the direct impacts of climate change on wild species. For this reason, Namibia must carefully consider how it develops these other sectors. For example, one of the most direct needs for adaptation as a result of climate change will be within the water sector, which needs to adopt at both national and transboundary levels, an Integrated Water Resource Management approach.

Large scale adaptation strategies with relevance to biodiversity conservation and protected areas include rehabilitating water basins through revegetation and riverine protection to contribute towards sustainable water resource management in line with predicted climate scenarios.

It is expected that climate change will affect human health in terms of water, food and air. In addition certain climatic events will have fundamental influences on exposure risks to new diseases that have shifted in their range or enlarged in their area of impact. Adaptation will be required especially when considering vector-borne diseases that already have an impact in Namibia, like malaria and diarrhoea. Infrastructure and organizational capacity is needed to prevent and control disease exposure and transmission, so that extra stress and risk to biodiversity, through inter alia, traditional medicinal demand, is minimised.

Similarly, reducing the impacts of unpredictable agricultural production is a top priority because smallholder farming is one of the main sources of livelihood for most of Namibia's rural population. Given that the worst impacts of climate change will be felt by the most economically vulnerable regions, the agriculture sector must emphasise (and equip communities to engage in) activities less susceptible to climate change than is the case today. Attention needs to be on water saving techniques as well as the most durable crops that can sustain food security but also can adapt to changing climate and soil regimes. Most important is that Namibians must distinguish between food security and food self sufficiency, since the two terms are often used interchangeably and in the wrong context. Given Namibia's biophysical characteristics, achieving food self sufficiency is unrealistic, but achieving food security should be a strategic objective. Also, it should be noted that food security can be obtained both by growing food as well as developing other activities, such as mining, manufacturing, tourism and service industries. The current obsession with growing food, often at the expense of a more sensible use of natural resources, should be resisted.

It is widely accepted that livelihoods diversification is a long term adaptation strategy that reduces vulnerability to climate change. This strategy is already inherent among most poorer households in Namibia as a means of coping with current levels of climate variability. Ideally, promotion of further diversification should encourage value added and higher income activities.

12.6 The 'bottom line'

In conclusion, climate change will result in major land use changes in Namibia. For example, fenced commercial ranching will tend to be replaced by more extensive low input systems, and cattle over much of the drier savanna areas will tend to be replaced by small stock. These changes will happen gradually without any intervention.

Since losses in production will be most acutely felt in the agricultural sector, active interventions are needed to shift toward the more resilient land and natural resource uses, as well as efforts to make land uses less rigid and more able to change and adapt. Recommended interventions thus involve more spatial mobility and focus on improved management of natural resources, and rangelands. They do not necessarily involve extending the state national parks, but rather extending the development of community and private conservation areas within the conservation network, particularly in those areas targeted as key in relation to losses in biodiversity. These interventions would largely amount to additional, focused CBNRM interventions in Namibia that build on the existing CBNRM programme.

The results of our analysis suggest that adaptation can be carried out in an economically efficient manner. This is an extremely positive result, in that adaptation simply to offset the potential costs of climate change is unlikely to be economically efficient when there is no added benefit derived from the adaptation measures, especially over the long time periods and given the high levels of uncertainty involved. In the case of transforming the protected areas patchwork into a protected areas network, and expanding and diversifying CBNRM activities, the benefits are anticipated to be greater than just the offsetting of potential losses due to climate change.

Financing will need to be found for some of these measures. While Namibia is unlikely to be able to generate significant revenue from afforestation/reforestation type carbon projects, opportunities for other types of carbon projects, such as concentrated solar power and small-scale biomass energy production, are worth exploring. Meanwhile, Namibia should also apply for adaptation funding in order to meet some of the challenges that lie ahead.

13 APPENDIX I. POLICY, LEGAL AND INSTITUTIONAL CONTEXT[15]

Peter Tarr & John Pallet

13.1 Introduction

This report assesses policies and institutions relevant to biodiversity and land and natural resources management, since Namibia's economy and people's livelihoods depend disproportionately on natural resources. Whilst this project is mostly about the vulnerability of Namibia's Protected Area Network to climate change, it is necessary to understand the broader policy landscape as the protected areas do not exist in isolation. This analysis excludes mining and minerals, which, whilst extremely important to the economy, are generally not affected by climate change.

The two key questions asked in this report are as follows - does the policy:

- reduce human risk exposure to climate change damages?
- Improve or maintain ecosystem resilience?

If the answer is yes, then the policy environment is conducive to achieving adaptation to climate change.

13.2 Key policies and laws relevant to land management and climate change in Namibia

The following policies and laws are regarded as key to the land and natural resources/climate change interface in Namibia (Table 13.1).

There are also over-arching policies, frameworks and conventions to which Namibia's policies should agree, such as the UN environmental conventions, Vision 2030, National Development Plans and the Poverty Reduction Strategy. These are included in the analysis to assess overall consistency and effectiveness with respect to land management and climate change.

[15] This analysis draws substantially on two previous policy and institution assessments conducted by SAIEA, namely:

- Review of existing institutional mandates, policies and laws relating to coastal management and proposals for change. Conducted on behalf of the Nacoma project in 2007
- Policy analysis for the Sustainable Land Management Support and Adaptive Management in Namibia project – 2009.

Contributors to the above work include Cormac Cullinan, Ted Rudd, Hartmut Krugmann, John Pallett and Peter Tarr.

Table 13.1. Key policies and laws, clustered into groups according to sector

Sector	Policies and laws
Agriculture	National Agricultural Policy (MAWF, 1995) National Drought Policy and Strategy (MAWF, 1997) Green Scheme Policy (MAWF, 2004 and revised in 2008) National Rangeland Management Policy and Strategy (MAWF, in compilation)
Water	National Water Policy White Paper (MAWF, 2000) Water Supply and Sanitation Policy (MAWF, 1993 and revised in 2008) Water Resources Management Act (2004, Presently Being Revised)
Forestry, Parks and Wildlife	Forestry Development Policy (Mawf, 2001) Forest Act (2001) Wildlife Management, Utilisation And Tourism In Communal Areas Policy (Met, 1995) Amendment To The 1975 Nature Conservation Ordinance (1996) Promotion Of Community-Based Tourism Policy (Met, 1995)
Land	National Land Policy (Mlr, 1998) National Resettlement Policy (Mlr, 2001) Agricultural (Commercial) Land Reform Act (1995) Communal Land Reform Act (2002)
Fisheries and coastal management	Territorial Sea And Exclusive Economic Zone Of Namibia Act 3 Of 1990 Sea Shore Ordinance Walvis Bay And Offshore Islands Act1 Of 1994 Namibian Ports Authority Act 2 Of 1994 Division Of Land Ordinance Of 1963 Town Planning Ordinance 18 Of 1954 Marine Resources Act 27 Of 2000 Aquaculture Act 18 Of 2002 Inland Fisheries Act 1 Of 2003
Environmental Planning	Environmental Assessment Policy (Met, 1995) Environmental Management Act (2007) Land Use Planning Towards Sustainable Development Policy (Met, 1994) Regional Planning And Development Policy (Npc, 1997)

13.3 Agriculture

A number of policies address agricultural production in Namibia directly, while others do so indirectly. The most prominent policies include:

- National Agricultural Policy (1995) – revision started in 2005, still ongoing;
- National Drought Policy and Strategy (1997)
- Green Scheme Policy (2004, revised in 2008)
- A National Rangeland Management Policy and Strategy is in compilation, led by the Emerging Commercial Farmers Support Programme in NAU.

13.3.1 Assessment of implementation of the agriculture policy cluster

Institutional aspects

The mandated institutions driving implementation of these policies are:

- The Ministry of Agriculture, Water and Forestry (MAWF), specifically the Directorate of Extension and Engineering Services (DEES);

- The Directorate of Agricultural Research and Training (DART), which carries out most livestock-related extension work;
- The Directorate of Veterinary Services (DVS);
- The Green Scheme drives implementation of all government – related irrigation projects. The Green Scheme Agency is the mandated parastatal to do this.
- The Emergency Management Unit (EMU) in the Office of the Prime Minister, and the Regional Emergency Management Units (REMUs) in the Regional Councils under MRLGHRD, are responsible for planning and carrying out disaster relief.
- The farmers' unions NAU and NNFU represent the freehold and communal farming sectors respectively.

The Drought Policy and Strategy is acknowledged to be very thorough and in line with sustainable land management but its recommendations are very poorly implemented. Implementation of the Green Scheme Policy is happening at a much slower pace than planned.

Severe limitations of finances, particularly for funding Green Scheme developments but also for most directorates, are partly to blame for this situation. Additionally, shortages of skills in irrigation farming, in DEES and DART advice givers, and in agricultural economists, all militate against pro-active agricultural promotion from the government. Timeous adaptive responses to drought situations (in terms of reducing livestock numbers in accordance with the carrying capacity at the time) are poorly achieved. Overall poor implementation of the policy cluster has a strong negative impact on ability to adapt to climate change.

13.3.2 Local level empowerment

Public participation and consultation was extensive for development of the agricultural policies. However, continuation of local level involvement has been poor, and there is very little effort given to empowering local level institutions for agricultural development. Namibia's Programme to Combat Desertification (Napcod) worked closely with DEES to establish Forums for Integrated Resource Management (FIRMs) at a few pilot projects, but the support to FIRMs stopped at the end of Napcod funding in 2004, and DEES has not attempted to sustain these forums, so they have stopped functioning.

The Emerging Commercial Farmers Support Programme was started in 2007 to assist this sector, particularly resettlement farmers, with major input from NAU in a mentorship role. Overall there is a marked absence of local level organizations to assist MAWF and development partners implement the directives in the agricultural policy cluster. This lack of ground-level involvement has a negative impact on ability to adapt to climate change.

13.3.3 Land productivity

Dryland cropping, particularly of mahangu, has led to gradual soil degradation through poor practices, exacerbated by the government-subsidised tractor ploughing services that concentrate on disc harrowing which compacts the soil and inhibits root growth. A recently started Conservation Tillage Project headed by DEES in Omusati Region aims to reverse this damage to dryland-cropping soils, improve soil fertility and simultaneously improve mahangu yields.

Green Scheme and private sector irrigation projects are mainly on the perennial rivers but they are also found around dams such as Hardap and Naute. Productivity of the land from these projects is high.

Bush encroachment is a persistent problem on cattle ranches (de Klerk 2004), predominantly on freehold land but also on communal lands. It is the outcome of poor livestock farming practices that include overgrazing, loss of grasses which gives small bushes an advantage, and absence of fires by purposeful management. The encroachment has resulted in losses of N$ 700 million annually to the farming industry (de Klerk 2004). It is lucky that losses in livestock production through bush encroachment can be offset by harvesting bush for charcoal production; nevertheless, the rangeland loses its potential for livestock production.

With respect to livestock productivity on communal lands: The intention of the Bull Scheme is to improve the quality of livestock that is offered for marketing. Perception in DART is that the standard of livestock is improved through the Scheme. However, the Scheme reaches only a very small proportion of livestock farmers, so its overall impact is limited.

Overgrazing, leading to loss of vegetation cover and crusting of the soil surface, reduces water infiltration to the soil and recharge of aquifers. As mentioned in the Water section, there are many cases of pollution of groundwater resources through nitrate contamination from kraals. This could easily be prevented by better siting of water points and kraals in relation to each other. The policies call for integration with other sectors, encouraging drought preparedness and sustainable natural resource management, all of which should enhance adaptation to climate change. The Rangeland Policy recognizes that there is a strong connection between productivity and stability of rangelands and biodiversity. However, the list of environmental problems associated with conventional freehold and communal farming and the growing need for farmland (land clearing, deforestation, overgrazing, soil erosion, bush encroachment) all have a negative impact on biodiversity.

13.3.4 Livelihoods

Agricultural policies and programmes are directed towards making agriculture economically productive, so that the products benefit the country as a whole and so that people are given opportunities to farm. Commercial livestock production and irrigated crop farming (dates, grapes, wheat, white maize) are successful economically and generate significant employment and incomes (Mendelsohn 2006).

Apart from the Green Scheme projects, MAWF has done little to expand crop-related business opportunities in communal areas. Milling enterprises have started, which help. Seed is provided at a subsidized price, but irregularities in supply make this an unreliable source. Judging by the level of informal marketing around Etunda, the Green Scheme clearly has had a positive effect on local livelihoods, and Oshakati and Outapi in the near vicinity allow easy marketing of vegetables. The increase in local economic activity is good for small-scale livelihoods.

DEES puts up livestock auction facilities, and water provision is facilitated through DRWS. Marketing of livestock in the Northern Communal Areas is still at a very low level. Meatco has tried to create incentives for people to market livestock, and was having limited success up to the time of the recent Foot-and-Mouth outbreak in Caprivi and Kavango in 2008. The quality of livestock brought for slaughter is generally lower than needed, despite the training that DEES and DART provide. Generally, there is a growing tendency for younger-generation farmers to make more use of market facilities, so change in set traditions is occurring. Farmers in northern Kunene market cattle and goats on a substantial scale. Income and livelihoods through livestock is therefore gradually increasing.

Providing livestock water to communal farmers during drought is seen as supporting rural livelihoods. However, this undermines adaptability to climate change, since the critical measure of carrying capacity is the condition of the pastures, not the water. The Drought Policy directive is to provide livestock water in keeping with the carrying capacity of the land, which varies continuously. However, emergency drought relief in the past has often sunk boreholes that were intended to be temporary relief for farmers, but that became permanent and spread the extent of overgrazing in areas that were previously used only seasonally. The impact of generally low crop and livestock productivity in communal lands is that livelihoods – including income, business opportunities, education possibilities, health and vulnerability to droughts – are not greatly improved.

13.3.5 Economics

The Agriculture Policy states that subsidies, which distort prices and discourage private sector investment in agriculture, should be ruled out. However direct subsidization from MAWF in agriculture is actually increasing e.g. in fertilizers, seeds, tractor ploughing and even weeding services. Such subsidization increases dependence on government services (which are often inefficient) and disempowers local business development.

The Green Scheme involves huge subsidization and has achieved some success. If the government wishes to build human and infrastructural capacity for irrigation farming, then this is a satisfactory way to do so (Price Waterhouse Cooper 2005).

Unfortunately, political interference in Green Scheme operations has jeopardized their viability. Poor management and irresponsible behaviour by some small-scale farmers (e.g. not repaying loans granted at the start) has been condoned, so that participants might now expect to be bailed out again in future. This promotes government wastage and unsustainable economic practices. The revised Green Scheme Policy has removed the leverage of private capital that was in the original version, and places the full responsibility for capital infrastructure on government. It also removes the requirement for training to be given to small-scale farmers. These revisions weaken the potential for the Scheme to attract skilled irrigation farmers, and weaken the Scheme's original purpose to build local capacity in irrigated agriculture. For these reasons, subsidisation through the Green Scheme is economically and socially less beneficial now than before the 2008 revision.

13.3.6 Political alignment

The policies are consistent with the Constitution but implementation is poor. NDP3 targets for irrigated and dryland agriculture seem unrealistically high. Targeted yields from dryland maize and mahangu are ambitious, but significant improvements have been reached through the Conservation Tillage Project, which needs to be rolled out extensively.

While there are no elements of the policies which directly conflict with the UNCCD, CBD or UNFCCC, the policies contain little in promoting novel agricultural production that goes beyond the status quo. Since it is conventional production methods that have created desertification problems, there need to be new approaches to solving these issues. Future pressure on natural resources will only continue to grow.

Adaptation to climate change and combating desertification should be encouraged through diversification of livelihoods. The policies are mostly silent on this. The Agriculture Policy promotes drought preparedness through improved early warning systems, which is only one small component of preparedness. Greater involvement of people on the ground in local level monitoring, coordinated through DEES, would be a more practical and immediate way of detecting the slow onset of drought. The policies, NDP3 and the Swapo Manifesto all proclaim greater agricultural production, but the budgetary allocation to agriculture has continually dropped since Independence. This shows a political mismatch between policy directives and financial commitment to carry them out.

13.3.7 Conclusions and recommendations

Summary of barriers to implementation

There is poor implementation of many aspects of this policy cluster.

A major constraint to improved implementation is the overall absence of local level organizations through which projects run by MAWF and development partners can be supported and driven.

Policy conflicts

The revised Green Scheme Policy (2008) does not build local irrigation expertise and conflicts with the Agriculture Policy directive to phase out subsidies.

Emergency drought relief borehole drilling conflicts with Rangeland Policy, Agriculture Policy and Drought Policy directives, as carrying capacities are exceeded and land productivity decreases when the water supply becomes permanent. A significant contradiction lies in the policy intention to improve livestock management. This is impossible for communal land owners who are not granted exclusive tenure over grazing resources (see Section 8.1.3).

Opportunities for synergies

Extension services provided by DEES concentrate on crops and livestock, while those provided by Directorate of Forestry (DoF) concentrate on forestry. Yet both services are hampered by lack of adequate staff and budget for traveling. Since DoF wishes to promote agroforestry, the extension staff from both directorates could be combined to cover extension support in both fields.

Recommendations

To improve local level empowerment, strengthen the Emerging Farmers Communal Support Programme with NAU. Additionally, revive FIRMs that were established under Napcod and roll out this approach much more broadly.

A standardized carrying capacity map is used as a guideline for stocking rates, yet carrying capacity varies markedly from year to year and place to place depending on where and when localized rains have fallen. Carrying capacity needs to be monitored on an individual farm basis and stocking rates adjusted accordingly. This can be done through the system of local-level monitoring (LLM), which was piloted in some Napcod project sites, and had reasonable success. This approach also forms a solid basis for early warning of approaching drought for the benefit of agricultural authorities and EMU / REMU authorities. The Green Scheme policy revision should be abandoned and the directives in the original Green Scheme Policy (2004) should be re-established.

More public-private partnerships for agricultural production should be built. Involvement of Agra, Meatco and other agricultural enterprises in training, livestock improvement, and rangeland management are positive moves in the right direction, and should be rolled out more widely.

As mentioned above, subsidies should promote a self-sustaining system that involves the private sector – they should not prolong people's dependence on government support. Finalize and start implementation of the Rangeland Policy as a matter of urgency. Subject all large-scale farming projects to environmental assessment. This is particularly directed to irrigation projects which have the potential for negative impacts from fertilizer and pesticide use, high water consumption and social issues around temporary labour requirements. The Drought Policy is very thorough yet urgently requires an implementation plan so that vulnerability to drought is significantly decreased.

13.4 Water

The water sector is guided by the following policies and regulations:

- Water Supply and Sanitation Policy (WASSP 1993)
- National Water Policy White Paper (2000)
- Water Supply and Sanitation Policy (WASSP 2008 revision)
- The Water Resources Management Act (2004, presently being revised)

13.4.1 Assessment of implementation of the water policy cluster

Institutional aspects

The Department of Water Affairs (DWA) in MAWF is responsible for allocation of water use permits and administration, while the Directorate of Rural Water Supply (DRWS) handles rural water provision and management. NamWater is responsible for bulk water supply and Local Authorities (LAs) for infrastructure and management in towns. Catchment-based management and planning (through Basin Management Committees), now being used by DWA, encourages much-needed integration between sectors.

Institutional aspects are not clearly spelt out in the policies, and strategies for implementation are mostly lacking. For example, the policies provide for progressive stepped tariffs (i.e. rising block tariffs) and cross-subsidisation in urban areas, which brings equity by assuring a minimum quantity of water for the very poor. However, few towns implement it and capacity at LA level is limited.

DRWS implements the Water Point Committee (WPC) system, which is a community-based management strategy for rural water points in line with the WASSP policies. Human resources for implementation by DRWS are inadequate. To improve this, installations are standardized as much as possible so that maintenance and upkeep are relatively simple. Much of the work is outsourced to the private sector.

Local level empowerment

LAs struggle to manage water infrastructure or other services. Widespread payment arrears by consumers makes water prices unaffordable for the very poor. DRWS has a good reputation for community based management (CBM) through Water Point Associations and Committees. Especially at community level, women play a substantial role in the CBM of the water supply systems. For the most part, maintenance of water points is the responsibility of the WPC and community, which encourages communities to maintain the equipment properly themselves. This, together with CBM, creates a stronger sense of ownership and encourages natural resource preservation in general.

Land productivity

Water consumption by rural consumers is generally low (Koch 2009). WPCs can potentially restrict water provision to livestock but in many cases do not, usually due to unfair influence exerted by relatively rich livestock owners. These 'cattle barons' are able to exert such influence since the lack of clear tenure arrangements allows them to build up large numbers of stock, which they then argue must receive adequate water. So long as the communal land tenure system is based on sharing of grazing resources, rangeland degradation and overgrazing around water points will continue.

Drought relief schemes generally increase vulnerability to climate change as water gets provided from emergency boreholes and is then used permanently thereafter, where it should have been shut down once the emergency situation had passed. A more effective way for assisting drought-stricken communities would be to provide water by tanker services, and only to maintain boreholes that become non-functional due to drop in groundwater levels or to increases in salinity. Groundwater quality is often compromised by pollution (mostly nitrates) from nearby kraals. This situation is easy to avoid by appropriate intervention and advice from DEES and DRWS officials. Apart from this problem, planning of rural water schemes includes recognition of the need to avoid or minimise environmental degradation.

Livelihoods

Water provision improves livelihoods and education opportunities, as water is now supplied to many more schools, and better access to safe water has led to a better quality of life, employment and business opportunities. Overall the impact of water provision and sanitation on urban and rural livelihoods and their ability to cope with climate change, is positive.

Economics

In urban areas, water demand management, effluent recycling and resource recovery make the use of water more efficient. This promotes development and reduces the need to exploit other water resources. Dewdney (1996) noted that water pricing should reflect the full cost of water provision as well as the opportunity costs, since water conservation efforts, without pricing incentives, have little impact. Where communities do not contribute towards water costs there are unsustainable expectations and wasteful consumption. These issues are addressed in the policies, where full cost recovery is desired for all water schemes. In rural water supply schemes, the community pays the full cost of an installation through the contributions of their labour and the price they pay for water to the WPC once the installation is operational. Similarly, pipeline schemes implemented by NamWater are supposed to be cost-recovered through the payments for water that are made once operational. However, concerns have been expressed that water is unaffordable and that higher water payments may push more people deeper into poverty (Falk *et al*. 2009) and increase their risk to climate change.

Political alignment

Consistency of the water policy cluster with the UN environmental conventions is generally good, through Namibia's water conservation practices and CBM approach. However, overgrazing caused by politically-motivated emergency boreholes goes against the UNCCD. In addition, urban sanitation goals are still far from their targets. In the NDP2 period, households with adequate sanitation rose from 30% to 41% (GRN 2008). NDP3 sets a target of 66%. Although this is obviously desired, it is unrealistic. Political support for the water policies is inconsistent and in certain cases, goes against stated policy.

13.4.2 Conclusions and recommendations

Summary of barriers to implementation

The lack of clear strategies on how to implement the directives of the policy cluster hampers implementation. Most especially, the lack of clear guidelines for implementation of the block tariff system is evident in inconsistent and incorrect application of the system, leading to inefficient water use and increasing resistance to paying. All of these symptoms reduce the ability to adapt to climate change.

Political interference is problematic since it undermines the principles of cost recovery and responsible management. Political support for the water policies is still only given in part, and in certain cases politicians have openly stated that people should not pay for water and other services.

Policy conflicts

Prioritisation of water use as set out in the WASSP (2008) places domestic requirements first, and subverts the environmental water reserve to below that. While the domestic demand for water is obviously important, the ability of the environment to provide the water sustainably should be the most important criterion.

The lack of clear guidelines regarding water pricing means that many LAs implement tariff systems that contradict the policy directives of equity and block tariffs.

Emergency drought relief schemes in the past have gone against policy by drilling emergency boreholes that have become permanent. This goes against the Drought Policy and the Agriculture Policy. The lack of exclusive grazing tenure on communal lands facilitates elite capture. Rangeland degradation and overgrazing around water points is the outcome, since WPCs often lack the authority to limit livestock watering for these people, or they are overruled.

Recommendations

The recently completed revision of the WASSP (2008) should be compiled in a user-friendly format with clear guidelines, and should be widely distributed to all LAs and MRLGHRD, MAWF and MOH offices, so that it can be properly understood and implemented. Develop a simple template for applying the block tariff system and give specific guidelines.

DRWS officials are concerned that there is inadequate integration between ministries that impact on land management, and that are therefore crucial in helping communities cope with climate change. Integration should be promoted at the technical level as that is where activities that directly impact on livelihoods and sustainable development have the most effect. The government agency which should be driving integration most forcefully is the regional councils, through the RDCCs.

13.5 Forestry and wildlife

Policies and regulations relevant to this sector include:

- Development Forest Policy (2001)

- Forest Act (2001)
- Wildlife Management, Utilisation and Tourism in Communal Areas Policy (1995)
- Amendment to the 1975 Nature Conservation Ordinance (1996)
- Promotion of Community-based Tourism Policy (1995)
- Human-Wildlife Conflict Policy (2009)

13.5.1 Assessment of implementation of the forestry and wildlife policy cluster

Institutional aspects

The Directorate of Forestry (DoF) in MAWF drives the forestry policy. There is much overlap with wildlife conservation because areas that have a conservation focus automatically protect natural habitats, which includes trees. In this sector there is a trend away from conventional forestry towards community-based management and non-timber benefits from forests. Forestry intentions are often subverted by higher national priorities. For instance, an aim of the DoF is to reduce the rate of deforestation. But, because food production takes higher priority, demands are made for land clearing and forestry has to concede areas it was managing. Clearly there is a need for zoning for optimum land uses in different areas.

Government financing for DoF is inadequate and human resources are limited. DoF extension services are severely understaffed but rather than combine forces with DEES, the forestry officials prefer to work separately.

The CBNRM programme is mainstreamed into MET's vision, donor interest and NGO support have been maintained, and local governance structures and procedures are being strengthened. There is a need within this sector to expand the scope of resources that fall under community based management, to include rangelands and fisheries, and to integrate the community based management of all of these resources much more strongly.

Human-wildlife conflict is likely to become more important as climate change sets in, due to the increasing pressure of rural communities on PAs, and the increasing role of wildlife in livelihood diversification. This is addressed by the Human-Wildlife Conflict Policy (2009), which calls for pro-active measures to prevent conflict situations arising, and greater capacity in MET for solving these problems when they occur.

Local level empowerment

In 2007 there were 13 established Community Forests, and by 2009, 50 were either registered or seeking registration (DoF 2009). This rapid growth shows the strong support for the programme. Similarly, there were 4 communal conservancies in 1998, now there are 50 (representing 220 000 members) and a further 25 are being established. There is great variation in the level of development of conservancies, and their level of capacity to handle the aspects of wildlife management, governance, running the business and distributing the benefits. The growing pains are not unexpected, and governance and management abilities are gradually improving.

Since both conservancies and community forests allow for livelihood diversification and local-level land management, they could improve the ability of communities to cope with climate change.

Land productivity

Community forest legislation grants control over grazing rights, which can improve range management. Whilst tree planting is strongly promoted, many areas of Namibia have unconducive soil and climate conditions. Also, DoF nurseries sell exotic and/or unsuitable trees which require supplementary watering. The nurseries should only sell indigenous trees.

Conservancies in Kavango and Caprivi generally set aside riverine areas and wetlands for wildlife, so that crop farming does not occur at the water's edge where it can have negative impacts, and where it would undermine forest preservation. This is good land use practice.

Many conservancies have commonage areas for livestock, and these areas are hampered by the 'tragedy of the commons' scenario that is typical in many communal areas. Recognising this problem, the CBNRM programme is promoting holistic resource management principles to improve the management of livestock in conservancy areas.

Improved resource management, focused on woodland or wildlife resources, has knock-on benefits due to the improved condition of the veld, so that below- and above-surface water resources are maintained on sustainability principles. Similarly, other components of biodiversity such as invertebrates, reptiles, birds are simultaneously conserved. Overall, land productivity, particularly in areas that are marginal for livestock or crops (much of Namibia), is improved under conservancy management. This is because part and parcel of the management plan is ensuring sustainable use of the natural resources.

Livelihoods

The Forestry Policy does not address the growing biofuel sector and potential *Jatropha* plantations in north-eastern Namibia. Cabinet has recently issued a statement that it does not support biofuel production through *Jatropha* because it threatens food production. It will only support research on *Jatropha* on a limited scale. It is a controversial point whether this is a lost opportunity or a wise precaution. To help resolve the issue, MET has commissioned a Strategic Environmental Assessment of the biofuel sector in Namibia.

Community forests conserve local natural resources and allow sustainable harvesting of them, which brings in income. In 2007, the 13 community forests earned just less than N$500 000, mainly from the sale of firewood, timber and poles for construction, thatching grass and tubers of Devil's Claw. Conservancies get income from trophies, tourism, lodge levies and employment in tourism establishments, all of which bring significant community benefits. Income to conservancies in 2007 was N$39 million (NACSO 2008).

Many conservancies and community forests re-invest the income in social projects such as extra classrooms for the school, houses for teachers, and paid transport out of remote areas into towns. This raises the standard of living with knock-on effects on education possibilities, health and other social benefits. Sustainable natural resource management involves flexibility and diversification of livelihoods, both of which are promoted in conservation management which conservancies apply. The event book system involves ongoing monitoring of the wildlife resources, so that timeous offtake measures can be taken in the event of poor veld condition. This management approach of simple yet valuable monitoring of livelihood resources builds responsiveness to climate variability, which stands communities in good stead to cope with future climate change.

Overall, the impact of community forests and conservancies on communities is strongly positive, and land management is improved through these approaches.

Economics

CBNRM activities earned the Namibian economy close to N$223 million in 2007 (NACSO 2008). The programme is expanding to include indigenous plant products, conservation tillage projects and holistic resource management. The platform provided by conservancies allows a focus on business skills and expanding the enterprises. All of these developments promote economic development in remote rural areas.

Whilst benefits from conservancies may be modest at household level (NPC 2007), they diversify livelihood options for communities especially arid areas where farming is marginal. Conservancies therefore improve the ability of communities to cope with climate change.

Political alignment

The Forestry and CBNRM policy cluster is consistent with the Constitution, Vision 2030 and NDP3. Poverty reduction strategies stress the value of diversification, and this is what the policies achieve through strengthening the non-agricultural and informal sectors.

CBNRM applied to wildlife and forestry helps to conserve biological diversity, use biological resources sustainably, and share out the benefits arising from such utilization. These are the three main principles of the CBD. The attention to monitoring of the natural resource base through the event book system, and adjusting stocking rates annually by deciding on sustainable offtake levels, helps people to adapt to climate variability, which is expected to become more pronounced.

13.5.2 Conclusions and recommendations

Summary of barriers to implementation

Both MET and DoF have inadequate staff and finances. METs collaboration with NGOs and the private sector has helped overcome this problem, and more partnerships should be encouraged.

Policy conflicts and gaps

The Forestry Policy directive to plant trees to combat desertification is not appropriate, since many areas of Namibia can only support trees if they are given supplementary water. Tree planting as a remedy for desertification should only be promoted in areas where deforestation has removed much of the tree cover, and only trees that are naturally suited to the local conditions should be promoted there.

The Forestry Policy concentrates on wood issues, but is silent on two major consumptive uses of wood, cooking fuel and construction. DoF should attract investment in cheaper, alternative cooking fuels, since the greatest threat to wood resources comes from wood fuel. Brick-making enterprises are another preferable substitute to wood for construction. The Forestry Policy does not address the growing biofuel sector and potential *Jatropha* plantations in north-eastern Namibia.

Opportunities for synergies

DoF extension services and DEES both suffer from inadequate staff. It would appear to be an obvious synergy to join these two units, particularly since DoF wants to promote agroforestry more and forestry initiatives can help farmers diversify their livelihood options. DoF resists this suggestion (Hailwa, 2009) on the basis that "DEES staff are not familiar with forest and woodland issues and tree planting, just like DoF staff are not familiar with livestock and crop issues." However, some training and cross-fertilisation of ideas would potentially benefit both camps. In the interest of better cross-sectoral coordination and improved service delivery, combination of the two extension services is recommended.

Recommendations

Devolution of management and benefit-sharing responsibility should be encouraged so that community based management covers a wider scope of natural resources, not just wildlife and forestry. The two obvious resources for inclusion are rangelands and fisheries. As climate change puts pressure on conventional agriculture-based livelihoods, diversification into wildlife and other natural resources should be encouraged and the integration of community based management programmes should be prioritized. There needs to be greater focus on reducing the potential for human-wildlife conflicts.

The complaint by DoF that forestry takes second place to other land uses such as irrigation or crop farming emphasizes the need for land use planning and zoning for optimum land uses in different areas. Tree-planting should not be promoted as a cure-all for desertification. Government nurseries should emphasize indigenous, arid-adapted trees more, and fruit-bearing trees such as marula and mangetti to increase commercial harvesting and value-adding to these products .

13.6 Land

Policies to do with land allocation and redistribution include:

- National Land Policy (1998)
- National Resettlement Policy (2001)
- Agricultural (Commercial) Land Reform Act (1995)
- Communal Land Reform Act (2002)
- Draft National Land Tenure Policy (2005, not yet finalized)

13.6.1 Assessment of implementation of the land policy cluster

Institutional aspects

The Ministry of Lands and Resettlement (MLR) is in charge of land use planning, land allocation and resettlement. Land administration in communal areas is under the control of Communal Land Boards and Traditional Authorities. Regarding land allocation, the main tasks of the Land Boards are controlling the allocation of customary land rights by Chiefs and Traditional Authorities, and granting rights of leasehold on communal land.

Unfortunately, neither the envisaged Land Use and Environmental Boards (LUEBs), which should ensure sustainability led land use planning, nor the Inter-Ministerial Standing Committees on Land Use Planning (IMSCLUP) have been established. Without these institutions land use planning in government is largely sectoral, uncoordinated and sometimes contradictory.

State-led acquisition of land for resettlement has been through the 'willing buyer – willing seller' approach but is frustratingly slow, and MLR is considering expropriation of farms in the public interest (MLR 2005).

Resettled farmers receive inadequate support as MAWF provides little extension support to resettlement farms, and MLR has inadequate capacity (pers. comm. Shivute 2009). Furthermore, under the Communal Land Reform Act (CLRA), resettled farmers must be granted leasehold of the land they receive. Yet very few resettlement farmers have been registered, so rights to use this land as collateral for financial support are still mostly absent.

Overall, the institutional framework to guide and carry out land use planning, land allocation and resettlement is inadequate.

Local level empowerment

The role of civil society in supporting land reform is not mentioned in either the Land or Resettlement Policies. There is little attempt to create local level forums to address the many issues around land: private fencing of communal lands, grazing rights, land use planning and zonation, resettlement issues, etc.

With respect to resettlement, there are serious delays in the registration of lease agreements for beneficiaries. The delayed registration of lease agreements disempowers resettlement farmers since they lack tenure security and in the end it harms the beneficiaries who are supposed to be supported (Harring & Odendaal 2007).

The lack of local level involvement and empowerment increases vulnerability to climate change since an inadequate sense of security or responsibility to land that is being farmed, results in people's attitudes focusing on immediate benefits rather than long-term care for the land they occupy.

Land productivity

The CLRA places a responsibility on any person holding a customary land right or right of leasehold to manage land in accordance with the Soil Conservation Act of 1969. Under the Act land holders must prevent soil erosion or any disturbance of the soil which could lead to erosion or pollution of water from the soil. If this occurs the Chief, Traditional Authority or Land Board may suspend or cancel the right or leasehold. The regulations also refer to the need to protect pastoral resources under the Soil Conservation Act. Despite these deterrents, the Soil Conservation Act has never been brought to a conviction, even though soil degradation is common.

The Land Policy opens the way for communities to have proprietorship over certain renewable natural resources on the land. This includes Water Point Associations managing boreholes, and conservancies and community forests managing wildlife and forests. By contrast, grazing resources in communal areas have not been granted the same level of proprietorship under the CLRA, so this vitally important component of land management remains unregulated. Under the CLRA, grazing rights are granted to the lawful residents on the commonage of a traditional community but are subject to conditions laid down by the Chief or Traditional Authority. An individual or group cannot exclude others, and influential individuals (who are not necessarily lawful residents) can persuade a Chief to allow them to graze on a commonage. Thus communities do not have the right to prevent other people using land they might want to set aside for improved management, so there is no incentive to practice SLM themselves. Furthermore, the condition that any resident can keep up to 300 large stock or 1,800 small stock does not make any reference to carrying capacity, and with the relatively small area for commonages and growing number of residents, is inviting overgrazing.

Under the Draft National Land Tenure Policy, it is proposed that all villages should be clearly demarcated and registered, as well as their residents be registered, so that they become the recognized 'owners' of village land. This would at least formalize tenure of communal land at the village level.

In conclusion: the Land Policy has allowed exclusive user rights to be granted over some natural resources, which is positive impact in the context of climate change adaptation. However, the most sought-after farming resource, grazing land, has been left unresolved. This is the biggest cause of unsustainable land management on communal land.

Livelihoods

Community based management of water points, wildlife and forest resources on communal land all help to improve the ability of communities to adapt to climate change.

Many emerging commercial farmers are unable to develop the agricultural potential of the farms fully due to remoteness, inadequate skills, poor infrastructure, high debt burdens and other factors (MLR 2005). Also, the size of resettler plots (average 1,500 ha) are too small to be viable and most resettlement farms have very limited options for crops, so that source of livelihood is unavailable. There has been little diversification of livelihoods on resettlement or AALS farms. Post-settlement support packages are granted on lenient terms yet profitable farming by most beneficiaries is still elusive.

Economics

The Land Policy has made a significant positive impact on the economy where it allowed user rights to be granted over water, forestry and wildlife resources.

Livelihoods are successfully improved for some resettlement farmers, but for most they have not been improved (Harring & Odendaal 2007). The 2005 PTT report states that some individual resettlement farmers had increased their asset base, in some cases doubling their herds, but the average farm income was only N$7 000 per annum (MLR 2005). Thus most beneficiaries need a supplementary income to survive. This is far short of making the beneficiaries economically self reliant and creating jobs for others, which are objectives of the Resettlement Policy.

MLR recognizes that not enough support is granted to resettlement beneficiaries to achieve the small-scale commercial economy that is intended. The Emerging Commercial Farmers Support Programme does provide support but it is not enough to make a significant impact on the resettlement process. To make the programme successful, there should be far greater empowerment and training and substantial social and economic support.

Political alignment

Land reform through the Land Policy that has granted improved user rights to communal residents through conservancies, community forests and water point associations has been highly successful. This demonstrates the enormous value of involving and empowering local communities, building public-private partnerships, involving NGOs, and insisting on good governance and transparency.

The political necessity to reform the inequalities of pre-Independence land distribution is fully acknowledged (NAU 2003). The AALS is a good policy in that it encourages successful black commercial farmers to expand their operations and/or to move to freehold land, and frees communal lands for other black farmers. However the speed of land reform has been an issue in Namibia since Independence. By 2006, the combined AALS and resettlement scheme had placed 800 farms in black hands in the 17 years since independence; i.e. about 12% of all farms, or less than 1% per year. Of these, only about 209 farms, or hardly 3% of all commercial farms, had been resettled by poor people (Harring & Odendaal 2006). With the poor productivity of many of these farms, the redistributive land reform process is not helping progress to achieving the targets of Vision 2030.

MLR (2005) itself recognized the problem that poverty reduction could not be linked to land reform during elaboration of the National Poverty Reduction Action Plan. Since the impacts of the Resettlement Programme are mostly increased land degradation, it is also not in line with the UN environmental conventions to which Namibia is a signatory, nor does it help progress to the Millennium Development Goals or improve ability to adapt to climate change.

Taken in the broad sense, land reform can and should have poverty alleviation as its objective, through innovative programmes that grant land residents the right and the capacity to make productive use of natural resources in an arid climate (NACSO 2008). Conservancies and community forests do this by empowering residents to look after their environmental assets and receive income from them.

13.6.2 Conclusions and recommendations

Summary of barriers to implementation

The land policies recognize that MLR can only successfully implement the resettlement programme with cross-sectoral collaboration with other ministries. However collaboration with and participation of other ministries is poor, which slows down implementation and leaves emerging farmers inadequately supported. Current trends increase vulnerability to climate change since the farmers, usually with livestock as their only income, overstock the land and cause overgrazing and land degradation.

There are capacity constraints in MLR for land use planning and both funds and expertise to support resettled farmers are inadequate. Cumulatively these factors all undermine sustainability and climate change adaptation options.

Policy conflicts and gaps

The most serious gap in this policy cluster is the lack of community user rights over grazing resources. Communities have rights over wildlife, forest resources and water, but not over the land itself. This prevents farmers from keeping others off the land they might wish to manage sustainably (e.g. by resting it), prevents them from being able to raise capital loans using the land as security, and makes it unattractive for investors to start capital projects since the risk is high.

The resettlement objective "…. to give target groups an opportunity…to produce their own food with a view towards self-sufficiency" is in conflict with the Agriculture Policy and NDP3. Government has moved away from the goal of food self-sufficiency and rather strives for household food security (MAWRD 1995).

The Resettlement Policy, as it is presently implemented, conflicts with all policy directives to improve sustainable land management. The objective to help farmers become self-sufficient is unrealistic since resettlement units are too small to be economically viable. The situation is made worse by the inability of MLR to provide the necessary support to these emerging farmers, and the reluctance of other ministries to assist.

Recommendations

The Land sector should extend group user rights to grazing resources as its most urgent priority, as inadequate tenure is the biggest obstacle to improved land management on communal land. At the same time, the moratorium on private fencing of communal land should be enforced.

The LUEBs at regional and local level, and the IMSCLUP at national level, should be operationalised and resourced as a matter of urgency. Collaboration between ministries with respect to all facets of land allocation and land use should be facilitated by setting up local level forums. This recommendation has been made for the agriculture sector, and FIRMs or similar local level organizations could be established and supported through either MAWF or MLR.

Implementation of the Resettlement Policy needs to be improved so that beneficiaries are given stronger support by MLR and other line ministries.

13.7 Environmental planning sector

The Environmental Assessment Policy (1995) has recently been enacted as the Environmental Management Act (2007), but its regulations and implementation have not yet formally started. The Land Use Planning Towards Sustainable Development Policy (1994) by MET has informed and influenced the CBNRM Policy (MET 1995), but it has not been formalized into any legislation. The Regional Planning and Development Policy (1997), driven by NPC, is largely unknown in that Ministry.

13.7.1 Assessment of implementation of the environmental planning policy cluster

Institutional aspects

The Directorate of Environmental Affairs (DEA) in the Ministry of Environment and Tourism is responsible for implementing the Environmental Assessment Policy and the Environmental Management Act of 2007 (EMA), although the latter is not yet operational.

Capacity to guide and review EIAs in DEA is inadequate but the EMA enables this task to be outsourced (at the proponents cost) to the private sector if necessary. The pool of environmental consultants in Namibia is small and no certification is required for EIA practitioners at present.

Local level empowerment

There was a thorough process of public participation during formulation of the EA Policy pre-1995. However there was a 12-year gap before the EMA was promulgated, so interest and involvement has waned.

Land productivity and livelihoods

The Policy and the Act are intended to prevent or minimize environmental damage and sustain livelihoods of all impacted parties.

Economics

The Policy encourages thorough planning of development projects, including economic and social perspectives. This will have a positive impact on SLM, since 'white elephant' projects will hopefully be scrapped before they start and before they cause any environmental damage.

Project proponents and politicians are often keen to over-emphasise the economic benefits and under-emphasise the environmental costs. EIAs need to be thoroughly conducted and reviewed to ensure there are no hidden aspects.

Political alignment

The policies do not interfere with any of the provisions of the Constitution, Vision 2030 and NDP3, and are likely to make future planning more realistic through the environmental planning process which all government departments will be required to go through. In particular, the requirement in the EMA of 2007 to undertake an SEA for policies, plans and programmes, should help Namibia to guide development in such a way that vulnerability to climate change is reduced. Thus, the EMA is regarded as a frontline tool in avoiding or reducing climate change impacts.

13.7.2 Conclusions and recommendations

Summary of barriers to implementation

Since the EMA's regulations are not yet gazetted, it is not fully operational. Capacity to guide and review SEAs and EIAs in the DEA is inadequate, and this will require considerable improvement in number of staff and expertise for efficient implementation.

Recommendations

To ensure that only qualified EIA practitioners practice in the field, they should be certified as professional members of a representing organization.

13.8 Coastal management and fisheries sector

This section of the report is divided into three sub-themes, namely the definition of the coastal zone, land use and development planning along the coast, and the management of fisheries resources.

13.8.1 Defining the coastal zone

Namibia's rights in relation to the marine environment are determined by the Territorial Sea and Exclusive Economic Zone of Namibia Act 3 of 1990 and by the Walvis Bay and Off-Shore Islands Act 1 of 1994. Procedures for determining the inland boundary of the seashore (i.e. the high-water mark) are provided in the Sea-shore Ordinance of 1958. Namibia's southern boundary with South Africa is disputed and is the subject of international negotiations between the two countries.

The **Territorial Sea and Exclusive Economic Zone of Namibia Act 3 of 1990** (amended by Act 30 of 1991) determines Namibia's territorial sea, internal waters, contiguous zone, Exclusive Economic Zone (EEZ) and continental shelf in conformity with international law. It defines Namibia's territorial sea as the sea within a distance of 12 nautical miles from baseline (the low water mark). It establishes Namibia's internal waters as waters landward of its low water line or any other baseline.

In the 200 nautical mile EEZ established under the Act, Namibia may exercise powers to control the use and conservation of living marine resources. The continental shelf is regarded as State land for the purposes of exploiting non-living resources, such as minerals, including diamonds, and petroleum.

The **Sea-shore Ordinance**[16] provides for the determination of the actual position of the high watermark and empowers the Minister to make various regulations including resource use and coastal management. This Ordinance does not appear to have been implemented nor have regulations been made under it. Furthermore it is not clear which Minister is authorised to use the powers granted by the Ordinance.

The **Walvis Bay and Off-Shore Islands Act 1 of 1994** provides for the full integration of Walvis Bay and the off-shore islands into the national territory of Namibia.

13.8.2 Land use and Development Planning along the coast

There is no legislation in Namibia that requires the preparation of a coherent, national and regional land use framework but it is envisaged that this will be introduced when

[16] Ordinance 37 of 1958. The application of the Ordinance to Walvis Bay was affected by Proclamation 144 of 1982 (GG 8344).

the Draft Urban and Regional Planning Bill is enacted. Currently the establishment of towns and the subdivision of land are regulated by the Townships and Division of Land Ordinance of 1963 while the development and application of town planning schemes is regulated by the Town Planning Ordinance 18 of 1954. State owned land is controlled by the Ministry of Works, Transport and Communications but the Ministry does not routinely undertake land use planning.[17] The Ministry of Environment and Tourism has on occasions undertaken land use planning in respect of areas designated for nature conservation such as the coastal national parks.

The Town Planning Ordinance 18 of 1954 makes provision for the preparation and carrying out of town planning schemes. Important in the context of climate change, is that these schemes include:

"1. A contour or topographical map of the area;
6. Sewerage, drainage and sewage disposal.
7. The prohibition, regulation or control of the deposit or disposal of waste materials and refuse.
9. The reservation of land for Administration and local authority purposes of a public nature.
10. The demarcation or zoning of areas to be used exclusively or mainly for residential, business, industrial, and other specified purposes.
15. The preservation of buildings or other objects of architectural, historic or artistic interest and places of natural interest or beauty."

The Ordinance also provides for the continued existence as a body corporate of the Namibia Planning Advisory Board (NAMPAB).[18] The main function of the NAMPAB is to advise the Minister of Local Government and Housing in relation to town planning matters, but the NAMPAB is given wide powers and its functions include:

"(b) to formulate in general terms a town planning policy for Namibia …
(f) to advise and assist local authorities generally in connection with the preparation of town planning schemes; … and
(g) to advise the Minister on the subdivision of land situated outside an approved township or outside the townlands of such a township where either the subdivision or the remainder thus created is smaller than 25 hectares."[19]

Town planning schemes must be approved by the Minister[20] but the authority responsible for administering an approved scheme (usually the local authority) is given extensive powers to carry out and enforce the scheme. These include powers to remove, pull down or alter buildings or structural works which were in existence when

[17] Coastal Profile of the Erongo Region – August 1999, page 134.
[18] Previously the South West African Planning Advisory Board.
[19] Subsection 12(2).
[20] Section 21.

the scheme came into operation and which do not conform to the scheme and to reinstate land which was being used for a purpose which now contravenes the provisions of the scheme.[21]

In certain circumstances a person who suffers damage, incurs expenditure or whose property is injuriously affected by the coming into operation of a scheme is entitled to recover compensation from the responsible authority.[22] However the Ordinance provides that no compensation is payable in respect of certain types of restriction imposed by schemes, including provisions that: fix building lines; regulate the character, size, height, harmony, design or external appearance of a building; or that prohibit the use of land for a purpose likely to involve a danger to life or danger or injury to health or serious detriment of the neighbourhood.[23] Unfortunately, the Ordinance does not provide for the exclusion and limitation of compensation where town planning schemes impose restrictions in the interests of the protection of the environment or the promotion of sustainable development. Accordingly compensation may be payable if such restrictions are imposed in town planning schemes unless they can be justified on other grounds as well. (For example, it may be possible to justify restrictions on how close buildings may be situated to the high water mark on the basis that the restriction is imposed in order to reduce the threat to humans and properties imposed by sea level rise and storms.)

In addition, municipalities often prepare additional (non-statutory) development and structure plans. For example, Swakopmund has prepared a structure plan with a 15 to 20 year perspective which involves the urban design of the beachfront area. The plan was prepared with public participation and is due to be reviewed every five years.[24]

It is envisaged that the current system of land use planning and development controlled in Namibia will be comprehensively reformed by the enactment of the draft Urban and Regional Planning Bill and regulations made under it.[25] The Bill provides for the establishment of national, regional and urban structure plans, and the development of zoning schemes. It also deals with a variety of related land use control issues such as the subdivision and consolidation of land and the establishment and extension of urban areas. The long title of the Bill indicates that it is intended that this will be done in the manner that "will most effectively promote health, safety, order, amenity, convenience and environmental and economic sustainability in the process of development".

Despite the fact that the zoning schemes provided for in the Bill could be used to exercise control over the use of land along the coast, it is important to appreciate that as currently drafted, the Bill is unlikely to affect existing use rights significantly. From an

[21] Section 28(2).
[22] Section 32.
[23] Section 33(1)(b), (d) and (k) respectively.
[24] Coastal Profile of the Erongo Region – August 1999, page 136.
[25] We have been provided with a copy of the Bill dated 26 March 2003 and with a copy of regulations to be enacted under the Bill dated 18 February 2003.

integrated coastal management perspective the Bill and the regulations made under it suffer from the limitation that they are designed to regulate the use of land (which is defined in a manner that suggests that it does not include submerged land). This means that it is unlikely that a zoning scheme could be used to control any activities in the sea and, in any event, could not be used by a municipality in an area beyond its area of jurisdiction (e.g. in the sea).

13.8.3 Fishing and aquaculture

Marine fisheries are regulated by the Marine Resources Act (MRA), 27 of 2000 and inland fisheries by the Inland Fisheries Resources Act 1 of 2003, while aquaculture is regulated by the Aquaculture Act of 2002, all of which are administered by the Ministry of Fisheries.

The issues of direct relevance to vulnerability and adaptation to climate change are dealt with in Part VI of the MRA. It begins by prescribing the controls upon harvesting marine resources in Namibia.

The MRA prohibits:

a) the harvesting, in Namibia or in Namibian waters, of any marine resource for commercial purposes, except under a right, an exploratory right or a fisheries agreement;[26]
b) the use, in Namibian waters, of any vessel to harvest any marine resource for commercial purposes, except in terms of a licence;[27]
c) the harvesting, by a Namibian flag vessel, of any marine resource in any waters outside of Namibian waters where it does not have a licence; and
d) the harvesting, by a Namibian flag vessel, of any marine resources to which any international agreement applies, where this is not authorised by a right granted under section 33, an exploratory right granted under section 34, or a quota allocated under section 39, as the case may be.

Part VIII of the MRA prohibits certain methods of fishing and prescribes measures for the conservation of marine resources, the control of harvesting of such resources and for the protection of the marine environment.[28] The Minister is empowered to declare any area within Namibian waters, with the consent of the Minister under whose authority an area of state falls, and upon appropriate consultation with the competent authorities, to be a marine reserve for the protection or regeneration of marine resources.[29]

[26] Section 32.
[27] Licence issued under section 40.
[28] Section 47(3).
[29] Section 51.

The **Inland Fisheries Resources Act, 1 of 2003** regulates the conservation and protection of (freshwater) aquatic ecosystems, the sustainable development of inland fisheries resources and the control and regulation of inland fishing. The Act establishes an Inland Fisheries Council to advise the Minister.[30]

A licence is required to fish in any inland waters[31] using fishing gear regulated[32] by the Act. The Act prohibits certain fishing methods[33] and provides that a fishing licence does not authorise the holder to fish in an area that has been declared as a game park or a nature reserve under section 14(1) of the Nature Conservation Ordinance, 1975.[34]

The Act also prohibits, without the written permission of the Minister, the introduction of any species of fish into any inland water system or the transfer of species from one sort of water system to another, the import into Namibia of any live fish, and the export from Namibia of any live fish that have been declared to be endangered species.[35] Any authority empowered to authorise the erection or installation of any structure in the river or stream, may only exercise that power after consultation with the Minister.[36]

The Minister is also empowered to declare any area of inland water as a fisheries reserve for a variety of purposes including preservation of the aquatic environment and to protect, preserve or rehabilitate the natural environment of fish, related ecosystems including wetlands, lakes, lagoons, nursery and sporting areas which are essential to maintaining the integrity of an ecosystem, species or assemblages of species.[37]

The **Aquaculture Act 18 of 2002** regulates and controls aquaculture activities and provides for the sustainable development of aquaculture resources.

The Act requires the Minister responsible for fisheries, in consultation with the Aquaculture Advisory Council[38] to formulate a general policy with regard to aquaculture in Namibia with a view to –

"(a) the promotion of sustainable aquaculture;
(b) the management, protection and conservation of marine and inland aquatic eco-systems;
(c) the promotion and operation of aquaculture projects."[39]

---

30 Section 3.
31 Section 1 provides that: "'inland waters' means a river, stream, water course, lake, swamp, pond, dam, reservoir or other fresh water body, excluding a fresh water body situated on private property, other than property owned or controlled via any board, institution or other authority established by any law;".
32 Section provides that: "'regulated fishing gear' means- (a) a rod, reel, line and hook; or a net".
33 Section 17.
34 Section 18.
35 Section 19.
36 Section 20.
37 Section 22.
38 Established by section 3.
39 Section 2(1).

The Act specifically prohibits the introduction to Namibia or any Namibian waters[40] of any species of aquatic organism or any genetically modified aquatic organism, or the transfer of any species of aquatic organism for one aquaculture facility or location in Namibia to another, without the written permission of the Minister.[41] The Minister may not grant such permission unless the impact of any introduction or transfer has been assessed, where required, in accordance with any legislation or policy dealing with environmental assessments.[42] The Act also prohibits the import or export of aquatic organisms without the written permission of the Minister.[43]

Despite the fact that this Act is intended to promote the development of aquaculture, because aquaculture is highly sensitive to environmental quality (particularly the maintenance of good water quality and the absence of pathogens) the wide-ranging powers given to the Minister could be used to achieve a range of coastal management objectives and reduce the vulnerability of this sector to climate change.

Institutional aspects

The institutions responsible for managing human activities of most concern from a coastal management perspective are reflected in Figure 1 and are discussed below. As appears from Figure 1 and the discussion below, responsibility for coastal management is spread among several Ministries and agencies and there is no single agency responsible for planning or co-ordinating coastal management.

The Ministry of Environment and Tourism (MET) has primary responsibility for terrestrial environmental conservation but its role in relation to the marine environment is limited. This is due partially to a dispute as to whether or not its jurisdiction extends below the high water mark, and partially because key environmental legislation drafted over the last decade, has not yet been enacted or come into force.[44] The fact that this dispute has not been settled and the fact that crucial legislation has remained in 'draft form' for so long indicates inertia in the responsible ministries. MET is also responsible for providing leadership regarding Namibia's lucrative and fast-growing tourism industry – much of which is centred along the coastline. Responsibility for regulating the environmental effects of mining and petroleum exploration and production activities on the marine environment is shared

[40] Section 1 provides that: “"Namibian waters" means the inland waters of Namibia as well as the internal waters and territorial sea, as defined in the Territorial Sea and Exclusive Economic Zone of Namibia Act, 1990 (Act 3 of 1990) and includes the seabed up to the high water mark and further includes private water as defined under section 1 of the Water Act, 1956 (Act 54 of 1956);”

[41] Section 27(1).

[42] Section 27(3).

[43] Section 28.

[44] This include the Environmental Management Act, a draft Pollution and Waste Control Bill and a draft Parks and Wildlife Bill.

between the Ministry of Mines and Energy, the Ministry of Environment and Tourism and the Ministry of Agriculture, Water and Rural Development (MAWF). The Department of Water Affairs (DWA) in MAWF is responsible for controlling pollution of the land environment and the marine environment from land-based sources through the current Water Act.

Local level empowerment

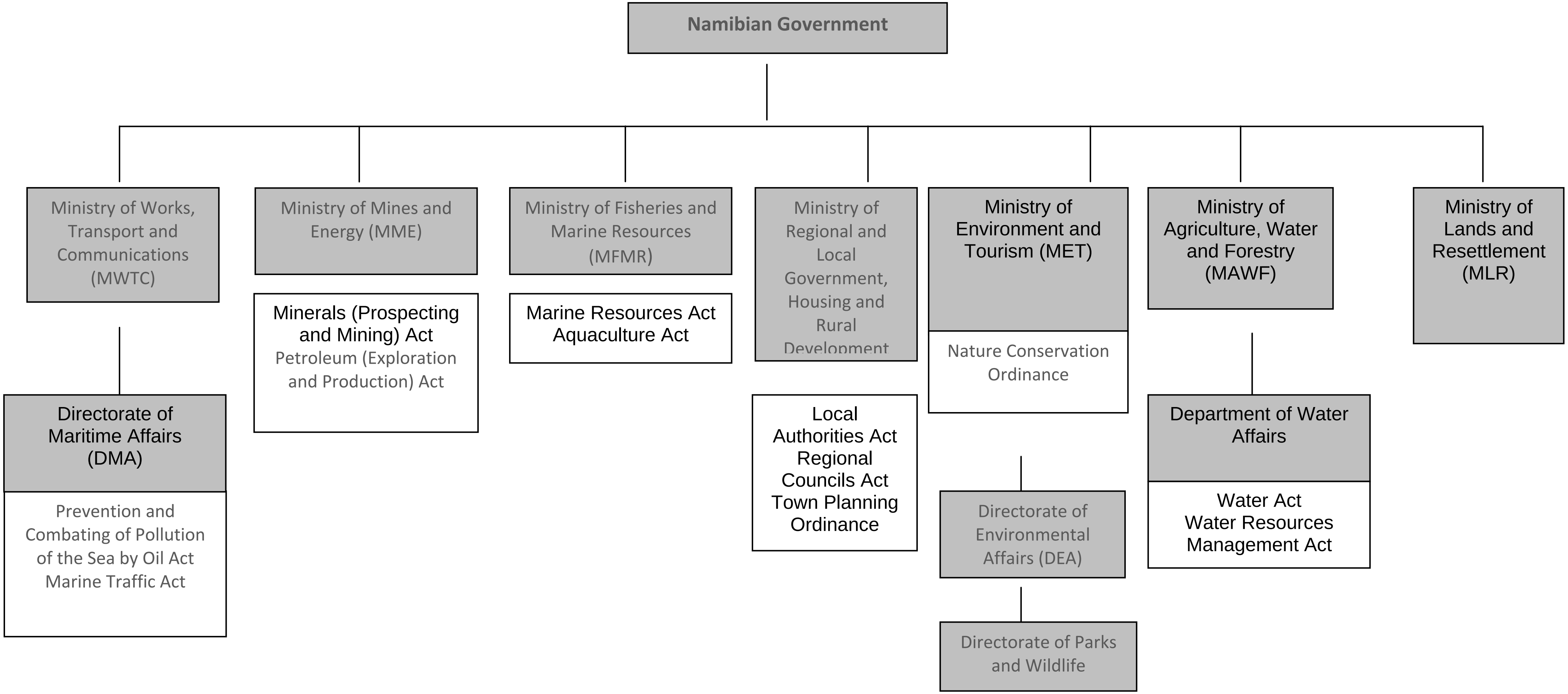
None, other than planning and management with municipal areas.

13.8.4 Conclusions and recommendations

The main conclusions and recommendations regarding policies and laws for coastal and fisheries management in the context of climate change are set out below.

1. Namibia has a number of laws that regulate human activities within the coastal zone but the existing legal framework has significant gaps from the perspective of integrated coastal management and does not provide an adequate basis for the effective implementation of integrated coastal management. There is no legislation that has the preservation of the coastal environment as one of its objects.

Figure 1 GOVERNMENT AGENCIES WITH PRIMARY RESPONSIBILITY OF ASPECTS OF COASTAL MANAGEMENT



2. The range of legal powers to implement effective coastal management would be greatly enhanced if the Water Resources Management Act, 2004 and the Environmental Investment Fund of Namibia Act, 2001 were brought into force, if the Environmental Management Act of 2007 was implemented, and the draft Pollution Control and Waste Management Bill and the draft Parks and Wildlife Bill were finalised, enacted and implemented. The latter will also require the making of regulations. This needs urgent attention.

3. New coast-specific legislation should be enacted:

i. to maintain, enhance and clarify the legal status of the seashore and coastal waters as the common property of all;
ii. to define the rights and obligations of both the public and the State in respect of the seashore, islands, tidal waters and adjacent areas;
iii. to define areas within the coastal area to enable different control measures to be applied within different areas and to provide a legally defined coastal zone for the purpose of implementing ICM;
iv. to provide for the granting and supervision of leases and concessions to use areas of the seashore and coastal waters;
v. to provide principles to guide-decision makers;
vi. to streamline the granting of authorisations for coastal activities that contribute to sustainable coastal development;
vii. to prohibit within coastal areas, activities that are particularly harmful to the coast and that can be undertaken elsewhere and to require environmental impact assessments for projects that may have a significant adverse impact on the coast (if this is not already provided for in other legislation);
viii. to establish a system for developing integrated and legally binding spatial plans and associated regulations for the purposes of implementing an ICM programme and for ensuring consistency between these and other sectoral plans;
ix. to clarify institutional mandates and enforcement powers; and
x. to give effect to Namibia's obligations under international law.

4. Line ministries and LAs need to significantly improve their governance regarding the allocation of various land and resource-use rights. These include prospecting and mining and urban expansion/development

5. There needs to be significant improvements in terms of building the capacity of the institutions with major responsibilities for coastal management.

14 APPENDIX II. POTENTIAL IMPACTS OF CLIMATE CHANGE ON NATURE-BASED TOURISM DEMAND IN NAMIBIA

J Turpie, N Gichohi, G Wilson, D Tuyisingize, A Skidmore, B Heermans, C Moseley, D Kujirakwinja, M Marias, Y Githiora, I Kissoon, S George & R Matsika

14.1 Introduction

The tourism industry in Namibia has undergone rapid growth since the late 1980s, with an average increase in international arrivals of 16% per year. Although there was a temporary setback in numbers following the 11 September 2001 attacks on the USA, recent statistics suggest that tourism has recovered its former rate of growth (Turpie et al. 2009). The tourism sector makes a substantial contribution to the economy, and is Namibia's fastest growing sector, with a growth of 11% compared to a global average of 6% in 2007 (Travel News, Namibia, 2009). Tourism in Namibia relies largely on the wildlife sector, in that most of the holiday tourists visiting Namibia are primarily interested in seeing the wildlife and beautiful landscapes. Changes in the quality of wildlife viewing, wildlife numbers and in the vegetation as a result of climate change may thus be expected to affect the demand for wildlife tourism, with negative repercussions for the economy.

Namibia is already a very arid country, with an average rainfall of 250mm (Barnard 1998). Climate change is expected to have a significantly negative effect Net Primary Productivity and wildlife carrying capacity (Midgley *et al.* 2005, this study). Arid areas are projected to increase, species composition will change and plants that will not have the ability to migrate are predicted to become critically endangered or extinct by 2080. The aim of this study was to describe the factors contributing to nature-based tourism demand in Namibia and predict the change in demand as a result of predicted changes in biodiversity under a range of climate change scenarios.

14.2 Methods

Holiday-makers were interviewed in Namibian National Parks (Etosha National Park, Waterberg Plateau Park, Sossusvlei/Sesriem National Park and the Fish River Canyon) and at Hosea Kutako International Airport in Windhoek. The surveys were designed and tested during the period 22 June to 28 June 2009 and administered in Namibia from 29th June to 5th July 2009. Interviews were conducted in English and German. In total, 472 questionnaires were completed.

14.2.1 Structure of the questionnaire

The questionnaires comprised three sections. The first section included basic visitor information about country of origin, type of trip (organised or self-drive), group size, length of trip and budget. Each interviewee was asked to give their total trip budget and the total amount of that being spent in Namibia. The surveys conducted in the airport included a list of all the National Parks in Namibia, and tourists were asked to tick off all parks that they visited whilst in Namibia.

The second section focused on factors of attraction in Namibia and the level of satisfaction that visitors gained from their trip. The priorities and interests of visitors to Namibia were assessed in terms how each of ten factors (landscapes, quality of wildlife viewing, quality of fishing and hunting, African culture and heritage, colonial culture and heritage, the languages spoken, climate, hiking/adventure/4x4 opportunities, quality of tourism establishments and service, and affordability) contributed to the visitors' decision in coming to Namibia, using a scale of 0 to 5. The visitors' level of satisfaction derived from their trip to Namibia was represented as a value out of 10 where 0 = no satisfaction and 10 = it can't get any better.

The third section focused on climate change and how it would possibly affect tourism in Namibia. Visitors were asked to rate five different scenarios which varied in terms of the coverage of the major biomes (Figure 14.1), abundance of Namibian 'specials', abundance and diversity of wildlife (including the big 5), and temperature. They were asked to score each scenario on a scale of 0 = no satisfaction to 10 = it cannot get any better. The rational for this is explained in more detail below. Visitors were also asked what the most they would be willing to pay to enter National Parks would be and were asked to rank the National Parks and Namibia in terms of value for money (excellent, good, fair and poor).

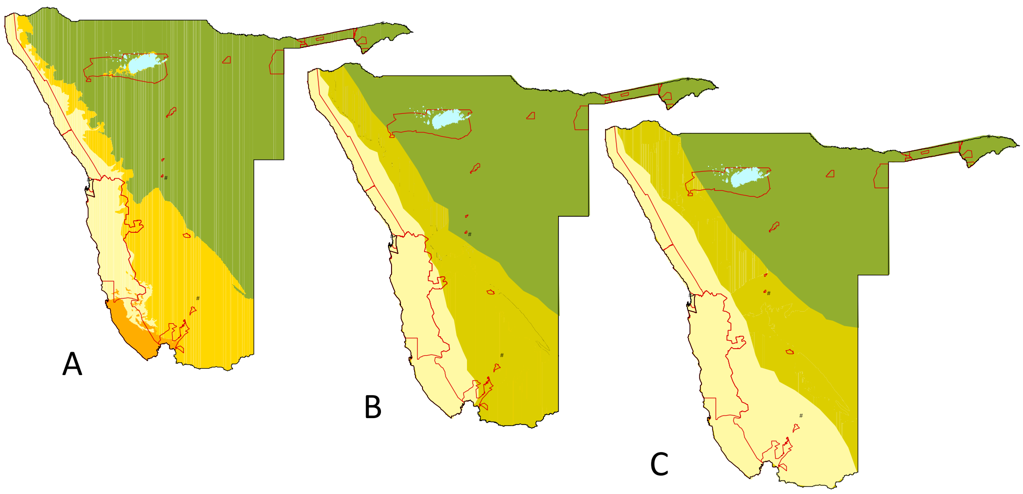


Figure 14.1. Hypothetical scenarios of changes in the distribution of biomes presented to respondents

14.2.2 Modelling climate change impacts

The impact of climate change on tourism in Namibia was calculated using the conjoint valuation (Turpie & Joubert 2001) method. Conjoint analysis is a statistical technique, most often used in marketing, to determine how people value various features that make up a package or service. The objective of conjoint analysis is to determine what combination of attributes of a package is most influential on respondent choice or decision making (Turpie & Joubert 2001). For this study the various features were the different attributes in Namibia that are likely to be affected by climate change. Interviewees were asked to score a range of scenarios which vary in the state of their attributes (Turpie & Joubert 2001). A multi-factor approach was used, where the interviewee was presented with a combination of all the attributes at one time. Four attributes were used, namely, vegetation cover, abundance of Namibian 'specials', abundance and diversity of wildlife, and temperature. Each attribute had a certain number of levels defined for it (Table 1). The levels of these attributes will vary with the different predictions for climate change.

TABLE 14.1. SUMMARY OF ATTRIBUTES AND ATTRIBUTE LEVELS

Vegetation Cover (V)	Abundance of Namibian 'Specials' (S)	Abundance & Diversity of Wildlife (including Big 5) (W)	Temperature (T)
A (as present)	20%	20%	as present
B (drier)	50%	50%	+ 3°C
C (much drier)	80%	80%	
	100% (as present)	100% (as present)	
	120%	120%	

With the four attributes and their relative levels, 150 possible combinations could be generated. Of these, 17 were selected and both a worse case and best case were included. MS Excel random number generator was used to eliminate impossible combinations of the attributes. The 17 scenarios were distributed among the five questionnaire versions. Respondents were asked to score each of the scenarios using a scale from 0 to 10, 0 being little or no satisfaction gained and 10 being a scenario that provides the most satisfaction.

Surveys that yielded unrealistic answers or where interviewees were uncooperative were excluded from the data analysis. A total of 437 surveys were used for the conjoint analysis. The relationship between the score given for each scenario and the different levels of the attributes was analysed using a multiple regression general linear model in STATISTICA (StatSoft, Version 8, 2007). The four attributes (vegetation cover, abundance of specials, abundance and diversity of wildlife, and temperature) were fitted to the score (Z) given for each scenario using the following equation:

$$\text{Utility index (Z)} = \text{constant (K)} + {}_1V + {}_2S + {}_3W + {}_4T$$

where vegetation cover (V) and temperature (T) are categorical variables and abundance of Namibian specials (S) and the abundance of wildlife (W) are continuous variables.

A utility score was generated from the above model for all of the attribute values and scenarios. The utility scores were converted into the time spent in Namibia by regressing the utility scores against the percentage time spent in Namibia (percentage of present) for the worst case, best case and status quo scenarios.

14.3 Results

14.3.1 Visitor numbers, group and trip statistics

A total of 457 tourist groups were surveyed, representing 2088 visitors. Visitors from SADC countries made up 39% of visitors surveyed, with Europeans making up most of the balance (Table 14.2). Of the total number of groups visiting National Parks only 3% (n=60) were Namibian. Of the SADC region, South Africans comprised 90% of the visitors. The average group size ranged between 3 to 5 with nearly equal numbers for visitors from Europe and southern Africa (Table 2). Visitors from SADC spent fewer days on average (14) than those from other regions. More visitors were on single destination trips than multiple destination trips (72% vs 28%), and more were on self drive than on organised trips (70% vs. 30%). Most of the tourists on multiple destination trips also indicated that their itinerary included visiting countries neighbouring Namibia with South Africa and Botswana having the highest representation (each 31% of respondents).

Table 14.2. The origins, group size and trip length of visitors to Namibia

	SADC	Europe	North America	Australasia	Asia
Number of groups surveyed	180	231	29	13	4
% of groups surveyed	39	51	6	3	1
Number of visitors represented	1021	892	124	36	15
Average group size	5	5	4	3	4
Average length of total trip (days)	14	36	44	70	17

According to surveys done at the Hosea Kutako International Airport in Windhoek, most of the tourists visited Etosha National Park and Sossusvlei/Sesreim National Park (Figure

14.2). None of the visitors indicated having visited Mahango Game Reserve and Mamili National Park.

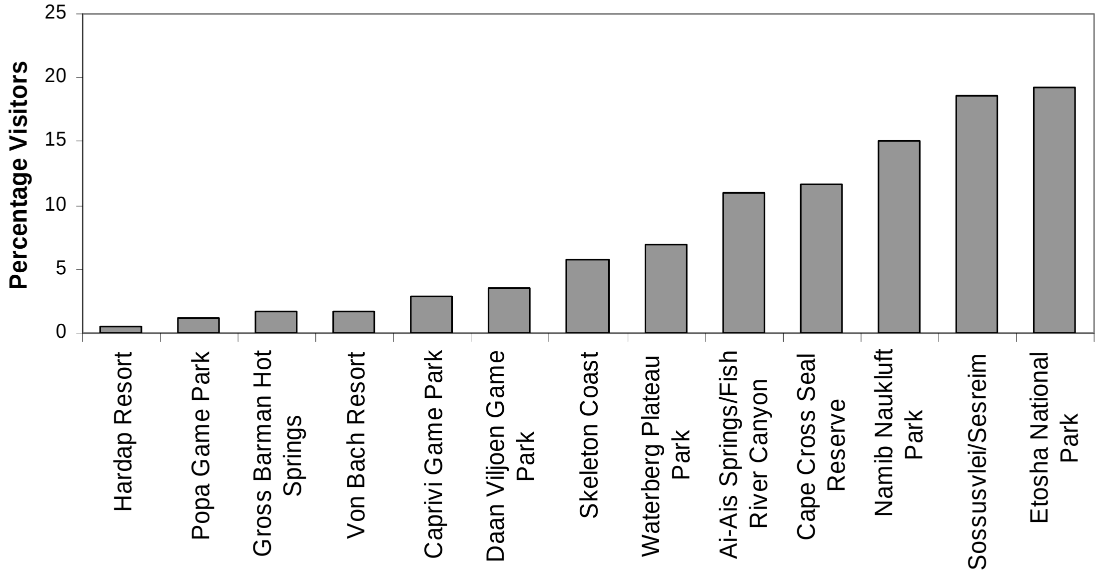


FIGURE 14.2. PERCENTAGE OF RESPONDENTS THAT VISITED THE DIFFERENT NATIONAL PARKS IN NAMIBIA

14.3.2 Factors attracting visitors

Landscapes and wildlife were the most important attractions for visitors choosing Namibia as their destination (Figure 14.3), and the lowest score was for fishing/hunting.

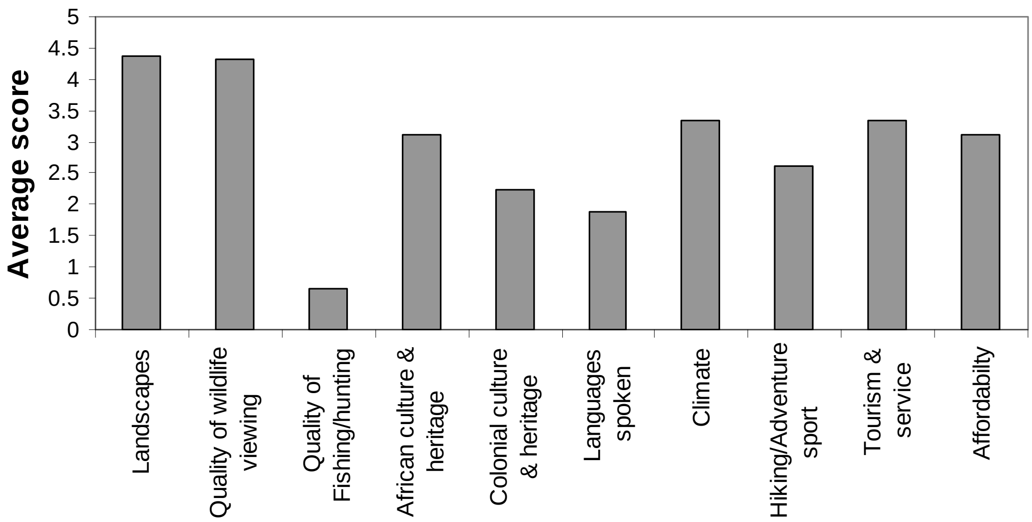


FIGURE 14.3. THE AVERAGE SCORE GIVEN BY VISITORS FOR EACH OF THE ATTRACTION FACTORS. THE RATING SCALE USED: 0 = NOT AN ATTRACTION TO 5 = A CRITICAL DECIDING FACTOR

Of all the nature attractions listed, the landscapes, wildlife viewing and seeing the big 5 contributed most to visitor enjoyment whilst in Namibia (Figure 14.4). Seeing the Namibian specials and fishing or hunting had smaller contributions to visitor enjoyment. Nature attractions were found to contribute on average 80% to tourist enjoyment and the average satisfaction gained by visitors was 8.5 (a score out of a maximum of 10). There was no difference between the SADC and non-SADC visitors for enjoyment and satisfaction gained from their trip.

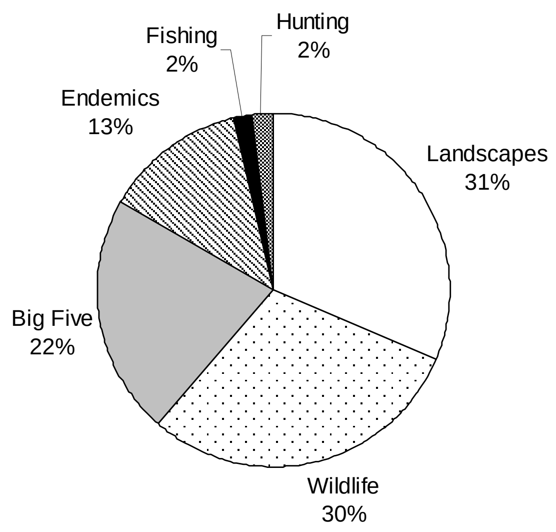


FIGURE 14.4. FACTORS CONTRIBUTING TO TOURIST ENJOYMENT IN NAMIBIA

14.3.3 Value for money of Parks and current WTP

Non-SADC countries had a higher willingness to pay for entrance fees into National Parks compared to the SADC countries. On average the Non-SADC countries were willing to spend N$247.50 and the SADC countries N$175.80 to enter National Parks. Thirty percent of SADC visitors ranked the National Parks as fair to poor in terms of value for money (Figure 14.5). Non-SADC visitors were happier with the National Parks in terms of value for money, 81% of the visitors ranked them good to excellent. When asked about the value for money in Namibia in general, SADC visitors increased their ranking with only 17% of the visitors saying fair to poor.

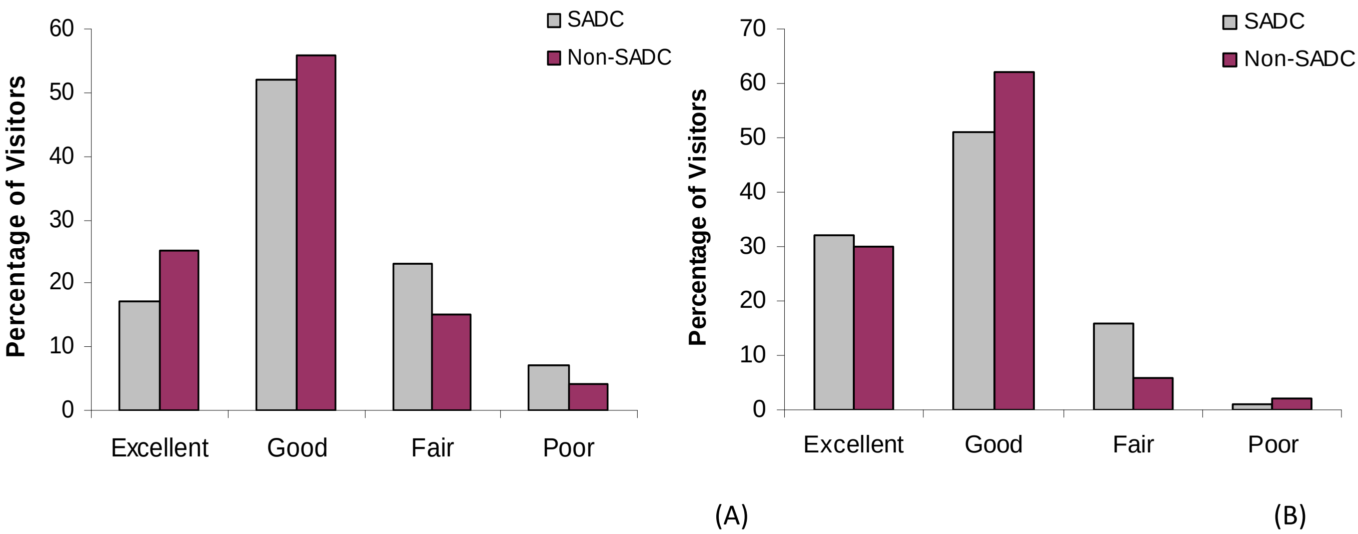


FIGURE 14.5. THE PERCENTAGE OF VISITORS RANKING (A) THE NATIONAL PARKS (N=261) AND (B) NAMIBIA (N=180) IN TERMS OF VALUE FOR MONEY

14.3.4 Potential impacts of climate change on visitor utility

The average scores for the different scenarios ranged from 9.0 for the "best" scenario to 3.0 for the "worst" (Table 14.3).

TABLE 14.3. THE AVERAGE SCORE GIVEN TO EACH SCENARIO AND THE CORRESPONDING VALUES FOR THE ATTRIBUTES

Scenario	Average score	Vegetation	Namibian endemics	General wildlife	Temperature
1	5.7	C	50%	100%	+ 3°C
2	6.3	A	80%	80%	As present
3	7.7	B	100%	120%	As present
4	5.4	C	80%	50%	As present
5	6.5	C	80%	120%	+ 3°C
6	6.0	A	50%	100%	+ 3°C
7	6.5	A	50%	120%	As present
8	8.3	A	120%	100%	As present
9	6.6	C	120%	80%	As present
10	5.6	A	80%	50%	+ 3°C
11	5.1	C	20%	100%	+ 3°C
12	6.0	B	80%	80%	+ 3°C
13	5.3	A	50%	50%	As present
14	5.9	C	120%	80%	As present
15	3.6	C	20%	50%	+ 3°C
Best	9.0	A	120%	120%	As present
Worst	3.0	C	20%	20%	+ 3°C

The utility score (Z) was predicted by the general linear model ($r^2 = 0.464$):

$$Z = 2.23 + (0.52 \text{ if } VA \text{ or } -0.38 \text{ if } VC) + 2.51\,W + 2.46\,E$$

Where VA is vegetation in state A, VC is vegetation in state C, W is general wildlife and E is Namibian endemic species. All the attributes, except temperature explain the change in scores.

14.3.5 Response to best and worst scenarios

From the respondents it was found that visitors were spending on average 16 days in Namibia (status quo). Under the worst case scenario this value dropped to 7 days and under the second worst-case scenario visitors would only spend 8 days. Under the best case scenario visitors would spend on average 25 days in Namibia. If the best case scenarios were reality, a typical trip would then have a value of N$23 773.80 (Table 7). In contrast if the worst case was the reality tourists would come for an average of only 7 days. The average trip would then have a value of N$8558.60.

TABLE 14.4. CONDITIONS AND VALUE PARAMETERS OF TOURISM UNDER THE THREE CASES

Amount of time spent in Namibia	Value (N$) of trip per person	Utility Index	V	S	W	T	Conditions
+6%	23773.80	8.66	A	1.20	1.20	As at present	Best
16 days	15405.40	7.63	A	As at present	As at present	As at present	Status Quo
-36%	8558.60	2.63	C	0.20	0.20	+ 3°C	Worst

14.3.6 Potential impacts on tourism

Based on the three scenarios (best, status quo and worst), the relationship between utility and average trip time (percentage of present) can be expressed as follows:

$$\text{Time spent in Namibia per trip} = 48.1 + 6.6636Z, \text{ (Figure 7, } r^2=0.9735)$$

Based on the utility equation, there was a positive correlation between utility score and the abundance and diversity of wildlife. As the Z score (utility) increased the percentage of wildlife increased (Figure 8, $r^2 = 1$).

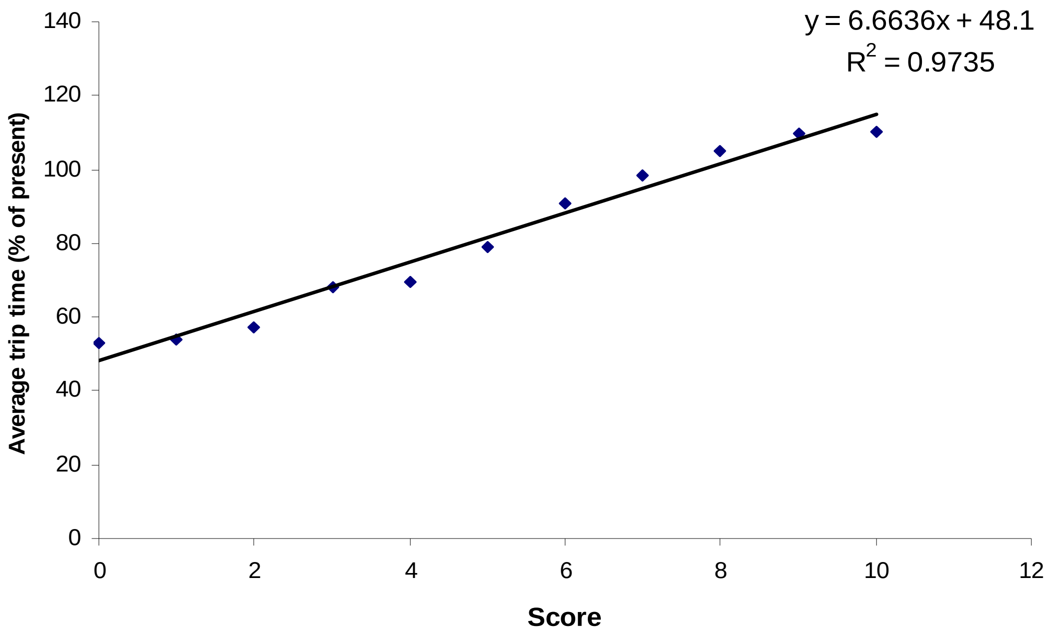


FIGURE 14.6. RELATIONSHIP BETWEEN UTILITY AND THE AVERAGE TRIP TIME (PERCENTAGE OF PRESENT) FOR TOURISM IN NAMIBIA

When values of vegetation, wildlife, Namibian endemics and temperature were set at those that are considered moderate, the Z score decreased to 6.83, which results in a 2.37% reduction in the time spent in Namibia (Table 8). Under the severe scenario, the time spent in Namibia is reduced by 15.01%. These changes in time spent in the country result in a N$1.2 million and N$7.4 million decrease, respectively in revenue for the national parks.

TABLE 14.5. THE POTENTIAL CHANGES IN Z (UTILITY) SCORE BASED ON MODERATE AND SEVERE SCENARIOS. THIS IS RELATED TO THE LENGTH OF STAY IN NAMIBIA AND THE CHANGE IN REVENUE TO THE NATIONAL PARKS

	Present	Moderate climate change scenario	Severe climate change scenario
Vegetation	A	B	C
General wildlife	100%	90%	50%
Namibian endemics	100%	95%	75%
Temperature	As present	+ 3C	+ 3C
Z score	8.5	6.83	4.95
Change in length of stay in country (% of present)	0	2.37	15.01

14.4 Discussion

The largest percentages of tourists to Namibia are from Europe and SADC countries, with the majority coming from Germany and South Africa. This is consistent with other studies (Turpie *et al.* 2009). International visitors spent on average a longer time in Namibia compared to SADC visitors, and many of these international visitors were on multiple destination trips.

Tourists are attracted to Namibia by the multiple nature attractions that it offers. Landscapes and the quality of wildlife viewing were found to be the most important factors attracting tourists. Other important factors that influenced the visitors' decision in coming to Namibia were the climate, African culture and heritage and the quality of tourism establishments and service. The landscapes and wildlife (including the Big 5) contributed largely to the enjoyment that the visitors gained from their trip. The National Parks capture most of these attractions and therefore play a leading role in trying to maintain and promote nature tourism in Namibia.

When evaluating the National Parks in terms of their value for money, SADC visitors ranked them lower than the international visitors. However, when ranking Namibia in terms of value for money the SADC visitors were far less harsh and had higher rankings. With SADC countries representing a large percentage of the tourist base visiting Namibia, it is important to take into consideration that National Parks might be becoming too expensive for regional and local visitors. Many of the visitors, especially groups from the SADC countries complained about the high costs of accommodation within the National Parks. Many of the respondents interviewed within the parks also indicated that they were staying in accommodation outside of the National Parks. This could result in tourists staying in private game reserves, with fewer visitors frequenting the National Parks. Government should therefore consider reviewing their prices for accommodation in the parks.

Nature tourism in Namibia seems to be fairly resilient to climate change predictions. When utility score is decreased considerably, the average time spent (percentage of present day) does not decrease at the same rate. Only under the worst case scenario of 20% wildlife and Namibian specials, much drier vegetation cover and a higher temperature did the utility drop below a score of four out of 10. With a worst-case scenario score of less than three, the average time spent in Namibia decreases by an estimated 36%. Given the extreme conditions described to respondents under the worst-case scenario, this suggests that the tourism sector will be robust to changes. This is to be expected, since landscapes and geographical features, which play a very important role in attracting visitors to Namibia, are unlikely to undergo any noticeable changes under climate change. Furthermore, the aridity of the landscapes lends them much of their current attractiveness.

Nevertheless, these results must be seen as fairly course. For example, some respondents had difficulty understanding the climate change scenarios, and many struggled to imagine their reactions.

Nature tourism is extremely important for the economy of Namibia, and from this study it has been shown that this sector may be more resilient to climate change than other sectors such as agriculture. Focussing on this sector may thus help Namibia to sustain economic outputs in the face of climate change.

15 APPENDIX III. ADAPTATION OF THE PROTECTED AREA SYSTEM TO CLIMATE CHANGE: A CONSERVATION PLANNING ANALYSIS

Phil Desmet, Guy Midgley and Jane Turpie

15.1 INTRODUCTION

This study provides a quantitative assessment of the impacts of climate change on the Namibian conservation network to fulfil its mandate of conserving the country's biodiversity. The assessment looks at the conservation network's ability to achieve current protected area conservation targets as well as the ability of the current conservation network to adequately conserve biodiversity given the anticipated future changes in the distribution of biodiversity due to climate change. Based on the assessment recommendations are made as to how to spatially adapt the conservation network to better fulfil its mandate given the anticipated changes.

Achieving adaptation to the impact of climate change is defined here as "facilitating the continued ability of the conservation network to meet conservation targets". Conservation targets are used in conservation planning as quantitative interpretations of our conservation goals. A conservation goal for a conservation network is usually something along the lines of "protect a representative portion of a country/regions biodiversity". Interpreting this goal as quantitative conservation targets may include targets such as "conserve 10% of each vegetation type" or "represent three separate populations of each species within the conservation network". Defining conservation targets is optimally performed on the basis of the best available scientific information, expert advice and international best practice. Therefore targets provide a useful means with which to measure the effectiveness of a conservation network in terms of meeting its mandate both in the present and under future conditions, and for our purposes here provide a quantitative measure of the ability of the conservation network to "buffer" the impacts of climate change by continuing to meet these targets.

Determining whether a conservation network has the ability to meet conservation targets now and into the future is limited by the availability of suitable data. Data are not only required on the current distribution of biodiversity, but more importantly are also required for the projected future distribution of biodiversity. For this study two excellent data sources were sourced, processed and utilized:

1. A vegetation-based Adaptive Dynamic Global Vegetation Model (ADGVM) dataset for southern Africa created by Scheiter & Higgins (2009) that predicts changes in 2080 in vegetation structure and biomass production over the sub-continent; and,
2. A species-based model dataset created by Broennimann *et al.* (2006) that projects the changes in 2080 in species distribution for 975 endemic southern African plant species.

This study is divided into two parts. The first explores how well the existing conservation network meets current conservation targets, or is representative of Namibia's biodiversity. The second part of this study looks at how well the current conservation network meets conservation targets given the anticipated changes in biodiversity distribution due to climate change. For both the current and future scenarios spatial options and constraints for improving the representation of biodiversity (i.e. meeting conservation targets) are explored and quantified with a view to reviewing the development vision for the Namibian conservation network.

The basic methodology followed in this study assesses gaps in the conservation network (i.e. how well does the conservation network achieve conservation targets) in both the current and predicted future biodiversity state, and then uses MARXAN conservation planning software to explore spatial options for addressing these gaps.

15.2 Methods

15.2.1 Data sets

To perform the assessment four groups of data were collated (Table 155.15.1):

1. Data on the current and future distribution of biodiversity:
    a. Current Namibian vegetation types
    b. Current agricultural land-types based on broad soil and rainfall groups
    c. Current modelled distribution of species at quarter degree square based on PRECIS herbarium records (approximately 18km raster grid).
    d. Steep, south-facing mountain slopes that act as local-scale climate change refugia for species. Calculated from the SRTM digital elevation model
    e. Predicted (2080) modelled species distribution based on PRECIS quarter degree square herbarium records and the HadCM3 General Circulation Model B2 IPCC SRES climate change projections (approximately 18km raster grid).
    f. Predicted (2080) average annual plant production interpolated from modelled biomass production using the ECHAM5 IPCC (2007) SRES A1B climate change projections (1km raster grid)
2. The current extent of the conservation network including all protected area status categories.
3. Context information that informs which areas have little or no biodiversity value and can be excluded from the analysis as making no contribution to achieving targets (e.g. urban areas, croplands and other transformed areas)
4. Context information that gives an indication of the relative "cost" of including additional areas into the conservation network (e.g. distance to urban areas or likelihood that areas will be required for other land-uses such as cropping agriculture or mining).

Spatial data were sourced from the Atlas of Namibia[45] the South African Biodiversity Institute (SANBI) and from this project.

[45] http://www.met.gov.na/programmes/infocom/infocom/atlas.htm

Table 155.15.1. Input data

Dataset Name	Description	Source
Biodiversity Distribution (Current)		
Vegetation Types	Namibian vegetation types (polygon shp file)	Atlas of Namibia
Agricultural Land-Types	Agricultural land-types based on broad soil and rainfall groups (polygon shp file)	Atlas of Namibia
Species Distribution	Current modelled distribution of species at quarter degree square based on PRECIS herbarium records (approximately 18km raster grid).	Broennimann *et al.* (2006) & Midgley *el al.* (2005) via Guy Midgley at SANBI
Climate change refugia (south-facing slopes)	Steep, south-facing mountain slopes that act as local-scale climate change refugia for species. Calculated from the SRTM digital elevation model	SRTM DEM v3 (http://www2.jpl.nasa.gov/srtm/cbanddataproducts.html)
Biodiversity Distribution (Future)		
Species Distribution	Predicted (2080) modelled species distribution based on PRECIS quarter degree square herbarium records and the HadCM3 General Circulation Model B2 IPCC SRES climate change projections (approximately 18km raster grid).	Broennimann *et al.* (2006) & Midgley *el al.* (2005) via Guy Midgley at SANBI
Net Primary Production	Predicted (2080) Average Annual Plant Production interpolated from modelled biomass production using the ECHAM5 IPCC (2007) SRES A1B climate change projections (1km raster grid). See Box 3.	Modelled biomass from Scheiter and Higgins (2009) Observed Average Annual Plant Production (average 1993-2000) from the Atlas of Namibia Average Plant Production interpolation by this project. Data available from Philip Desmet (factoryrider@absamail.co.za)
Protected Areas	An up-to-date map of the extent of all categories of existing and establishing protected areas in Namibia.	Atlas of Namibia and updated by this project. Available from Katharina Dierkes (maproom@iway.na)]
Context Information		
Land Cover	Approximate current extent of transformed areas (urban areas and crop-lands) (1km raster grid).	Urban areas – Earth@Nite dataset (http://www.ngdc.noaa.gov/dmsp/) Crop lands – Global Land Cover data from the Atlas of Namibia
Cost	A relative index of degree of difficulty of including a PU into the conservation network. Based on (1) weighted distance to settlements and (2) extent of transformed areas (urban and crop-lands), and summed per planning unit (1km raster grid)	Generated by this project from the land-cover datasets
Planning Units	The unit to which all input biodiversity, land-cover and cost information was summarized and assessed. Layer comprises a continuous coverage of approximately 9x9km polygons covering the entire extent of Namibia (total of 10477 planning units). PU's exactly ¼ size of species model pixel size (polygon shp file).	Generated by this project

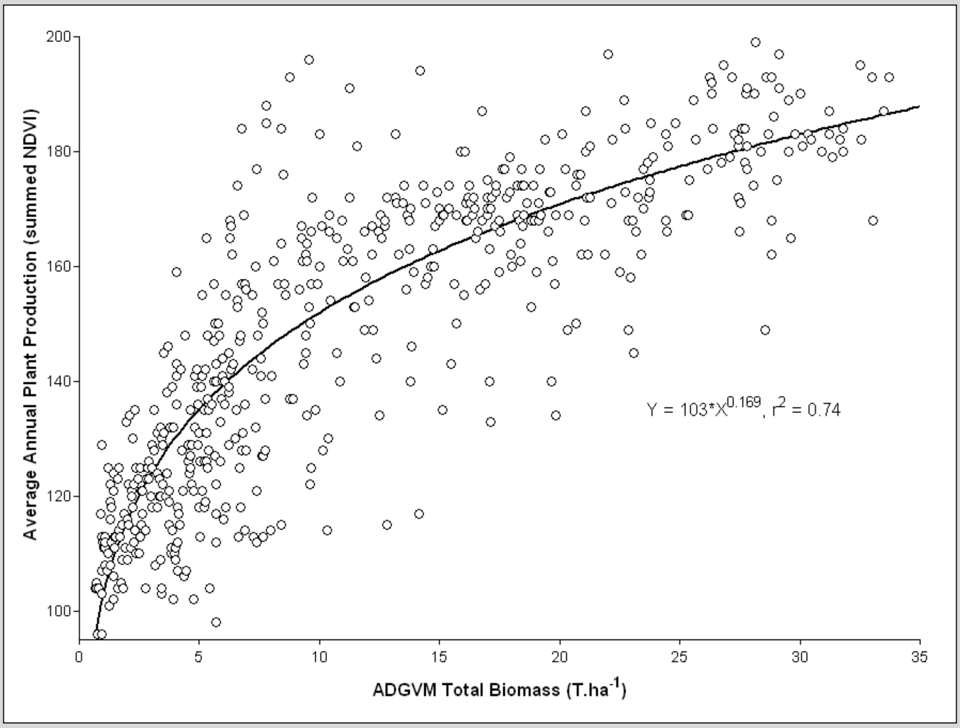
BOX 1. DOWN-SCALING OF ADGVM MODEL OUTPUTS

THE ADGVM VEGETATION MODEL DATA WERE "DOWNSCALED" FROM A 20KM TO 1KM GRID LEVEL BY RELATING THE MODEL OUTPUTS (TOTAL BIOMASS [PRESENT]) TO OBSERVED AVERAGE ANNUAL (SCALED) NDVI (1993-2000) (AVERAGE ANNUAL PLANT PRODUCTION FROM THE NAMIBIAN ATLAS).

PROCESS STEPS:

1. Demonstrate relationship between observed total annual plant production (1km) and modelled total biomass (20km).
2. Convert current and future total biomass to annual plant production using regression equation at 20km grid level.
3. Calculate delta or %change in total biomass at 20km grid level.
4. Interpolate delta from 20km to 1km grid level using latitude, longitude and elevation as co-variables.
5. Multiply current plant production (1km) by delta (1km) to produce 2080 predicted plant production.

Data were interpolated with ANUSPLIN interpolation software (Hutchinson, 2001) and using the Integrated Toolset ANUSPLIN interface extension for ArcView 3 (http://www.daff.gov.au/brs/climate-impact/toolset).



The observed relationship between modelled current total biomass and observed current plant production (relative unit).

15.2.2 Conservation Targets

Namibia does not have an explicit conservation network target, i.e. the amount of land the government wishes to formally set aside for biodiversity conservation. In order to evaluate the biodiversity representivity of the conservation network we set conservation targets (viz. protected area targets) for the features included in this analysis based on current international guidelines (Langhammer *et al.* 2007) and approaches elsewhere in the region (Driver *et al.* 2003, Driver *et al.* 2004). These were 15% of the original extent of all vegetation types and agricultural land types, 50% of the original extent of south-facing slopes (which are assumed to act as refugia in arid landscapes), and 10% of the area of occupied by each species (using occurrence in planning unit as a surrogate) (Table 155.1.2).

In addition, because of the relative unreliability of species distribution projections, we introduce primary production (PP) as a novel target in this study in order to evaluate the performance of the conservation network under climate change (Table 155.1.2). We set the target as either being equal to the sum of primary production in the conservation network at present, or as being equal to the proportion of regional PP held in the conservation network at present. The rational for this is that primary production is expected to change over much of the existing conservation network. Adjusting the conservation network to maintain current levels of primary productivity is assumed to maintain the same level of abundance of wild plant and animal populations because of its relationship to carrying capacity (e.g. Desmet, 2004; Berliner and Desmet, 2008). Note that this does not necessarily look after species who are narrow in their habitat requirements or less able to shift their distributions.

TABLE 155.1.2. SUMMARY OF TARGETS USED IN FOUR GAP ASSESSMENT SCENARIOS. THE CURRENT SCENARIO LOOKS AT THE CURRENT REPRESENTIVITY OF THE CONSERVATION NETWORK. FUTURE 1 LOOKS AT THE CURRENT CONSERVATION NETWORK MEETING TARGETS FOR THE FUTURE PREDICTED DISTRIBUTION OF SPECIES. FUTURE 2 ASSESSES THE ABILITY OF THE CURRENT CONSERVATION NETWORK TO MAINTIAN THE CURRENT PP LEVELS BASED ON THE FUTURE PREDICTED PP. FUTURE 3 ASSESS THE ABILITY OF THE CURRENT CONSERVATION NETWORK TO REPRESENT AN EQUAL PROPORTION (40%) OF EACH REGIONS FUTURE PREDICTED PP.

Biodiversity Feature Group	**Current**	**Future1**	**Future2**	**Future3**
Vegetation types	15% of original extent	-	-	
Agricultural land-types	15% of original extent	-	-	
South-facing slopes	50% of original extent	-	-	
Species	10% of current occurrences[1]	10% of 2080 occurrences	-	
Primary Production			Sum of conservation network in 2009	Equal proportion of eco-region PP in 2080

1: Species were recorded only as present/absent in a planning unit therefore 10% of occurrences implies 10% of planning units in which species was recorded.

15.2.3 Planning units

The planning domain (viz. Namibia) was divided into 10788 equal-size 9x9km or 18000ha conservation planning units (PU). The minimum size of the PU was limited by the scale of the species input data. Species were originally modelled at an approximately 18x18km grid cell size and it was not possible to down-scale this information without going back to the original modelling process. Therefore a compromise had to be made between using smaller planning units that are more suited to the level of conservation decision making (i.e. cadastre-level or below, ca. 500-2000ha) versus a planning unit that better matched the spatial resolution of the input data. Each species model grid cell comprised exactly 4 planning units and it was assumed that a species was equally likely to occur in each planning unit if it was encountered in the corresponding model grid cell. We acknowledge that this is not necessarily valid especially for endemic species that tend to be restricted to particular habitats and are not encountered equally throughout the landscape or a QDS in which they are recorded.

PU cost was the same for the current and future scenarios. This is a potentially problematic assumption as the relative PU cost is likely to change in future given expected changes in population size and patterns of land-use (e.g. urban expansion, abandonment of agricultural areas). Given the time constraints of this project preparing future PU cost scenarios was not conducted.

PUs that were more than 40% transformed were excluded form from the analysis. For future scenarios PUs excluded due to urban areas were expanded by one PU to take into account likely expansion in major urban areas between now and 2080. In total for current scenarios there were 61 or 0.56% of sites excluded vs. 223 or 2.07% of sites for the future scenarios.

15.2.4 Protected Area System

For the purposes of this analysis all categories of current and establishing protected areas were considered as contributing towards achieving targets. The conservation network covers 45% of the country or approximately 37 147 714ha (Figure 15.1.1), but only 39% of this comprises state-owned protected areas (Table 15.1.3). The objective of this exercise was not to compare the relative contribution of the state vs. private components of the conservation network towards achieving targets. With nearly 60% of the conservation network comprising privately/communally owned conservancies clearly conservancies play a major conservation role in Namibia. Assessing the conservation management effectiveness of conservancies is a topic for another discussion.

TABLE 15.1.3. A SUMMARY OF THE PROPORTIONAL COMPOSITION (% OF TOTAL CONSERVATION NETWORK AREA) OF PA CATEGORIES AND OWNERSHIP TYPES MAKING-UP THE NAMIBIAN CONSERVATION NETWORK.

PA Category	Ownership				Total
	Emerging	Gazetted	Private	State	
Commercial conservancy	0	0	13.4	0	**13.4**
Communal conservancy	10.1	35.8	0	0	**45.8**
Community forest	0	1.1	0	0	**1.1**
Private nature reserve	0	0	1	0	**1**
Protected area	0.3	36.6	0	0	**36.9**
State concession area	0	0	0	1.8	**1.8**
Total	**10.3**	**73.4**	**14.5**	**1.8**	**100**

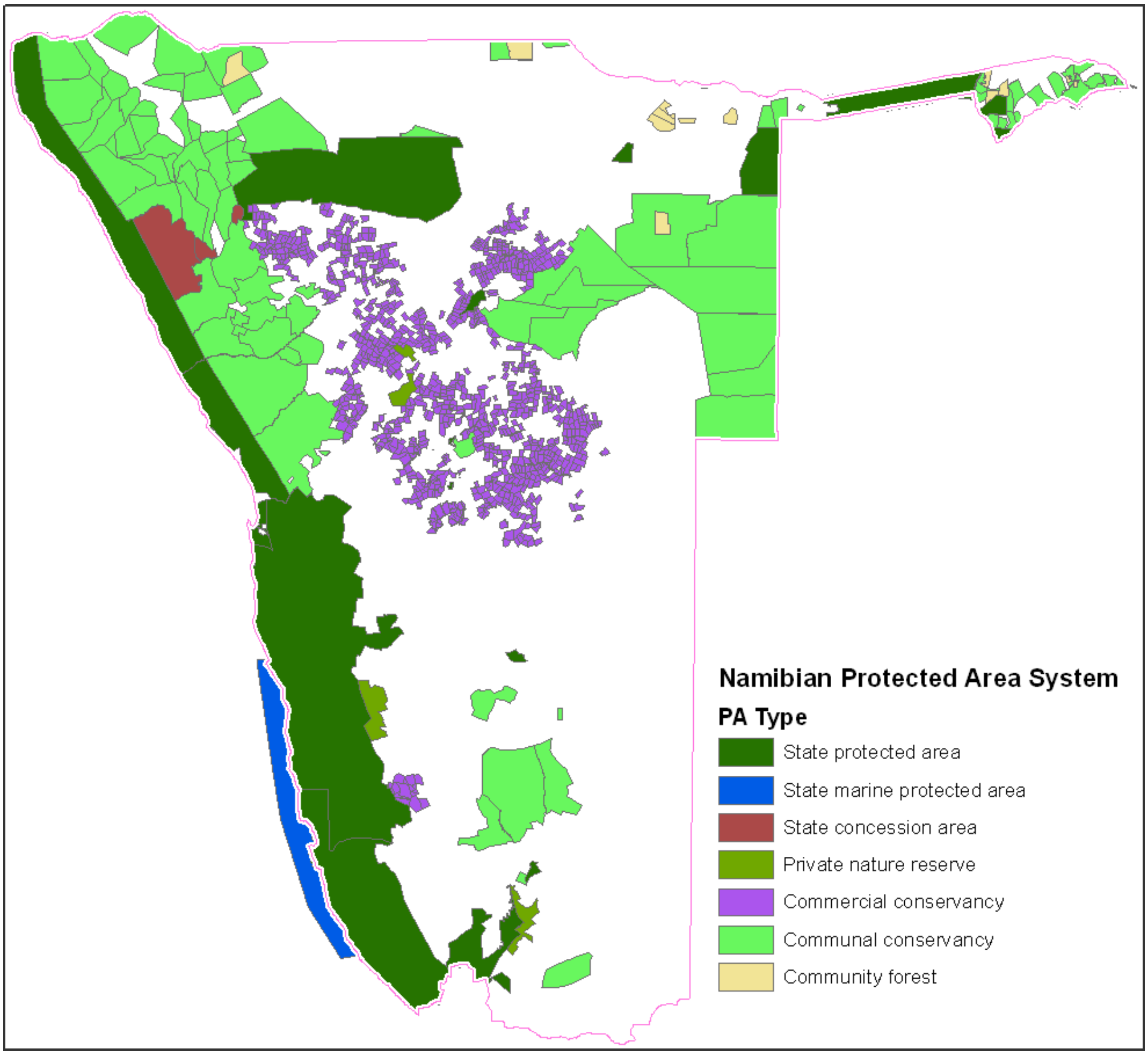


FIGURE 15.1.1 THE EXTENT OF PROTECTED AREAS IN NAMIBIA.

15.2.5 Eco-regions

For the purposes of the primary productivity analysis the country was divided into 12 broad bio-climatic eco-regions based on biomes and basic geo-morphological regions. The rationale for this subdivision was to provide a coarse national-level stratification of the country with which to test the representivity of the conservation network in terms of capturing an equal proportion of each region's PP.

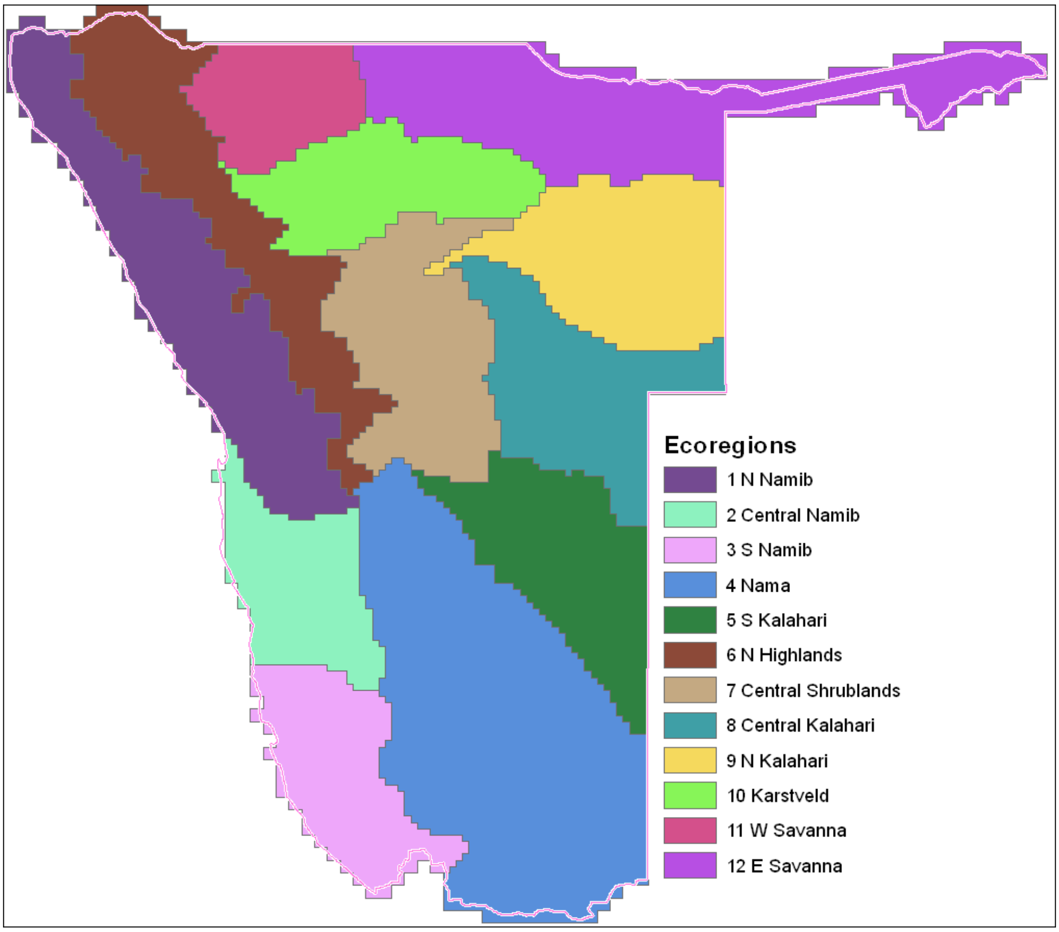


FIGURE 15.1.2. BROAD ECOREGIONS USED TO SUMMARISE PP DATA IN THIS ANALYSIS.

15.2.6 Software

The spatial options assessment was conducted using MARXAN conservation planning decision support software (Ball and Possingham 2000; Possingham *et al.* 2000) with the CLUZ extension for ArcView 3 GIS (Smith 2004).

MARXAN is software that delivers decision support for reserve system design (Ball and Possingham 2000, Possingham *et al.* 2000). The basic idea behind a reserve design problem is that a conservation planner has a large number of potential sites (or planning units) from which to select new conservation areas. They may wish to devise a reserve system which is made up of a selection of these planning units which will solve a problem that includes several ecological, social and economic criteria and principles. MARXAN is primarily intended to solve a particular class of reserve design problem known as the ‘minimum set problem’, where the goal is to achieve some minimum representation of biodiversity features (i.e. achieve targets) for the lowest possible cost. The rationale is that less costly or socially disruptive reserve networks are more likely to be implemented. Furthermore, meeting a set of targets for all conservation features provides a solid platform for expanding a reserve system in the future; reserve systems biased to habitats of high commercial value are often hard to expand. In minimum set problems the elements of biodiversity that you wish to conserve are entered as constraints to solutions of the problem (Possingham *et al*. 2000). Given reasonably comprehensive data on species, habitats and/or other relevant biodiversity features, MARXAN aims to identify the reserve system (a combination of planning units [PUs]) that will meet user-defined biodiversity targets for the minimum cost (Ball and Possingham 2000, Possingham et al 2000).

The key variables in determining a MARXAN solution are:

1. Conservation targets (see Section 0)
2. PU cost – or the cost of selecting a particular planning unit. The cost used in MARXAN can be the monetary value of a PU or any relative social, economic or ecological measure of costs, or combination thereof.
3. Boundary Length Modifier (BLM) – a weighting factor that promotes the selection of more compact solution or a more desirable solution comprising a reserve network of a few large contiguous reserves rather than many small scattered reserves. The boundary length is the sum of exterior boundaries of a reserve solution. BLM is a function of the total number of *available* planning units (i.e. total boundary length), and is not influenced by PU cost, conservation targets or number of features. A more fragmented reserve network will have a greater overall boundary length. It is this boundary length, plus a weighting on its importance (the BLM or boundary length modifier) relative to the other components of the objective (cost and meeting targets), that can be included in the objective function. For the purposes of this analysis we chose to limit the influence of boundary length by setting a constant BLM for all current or future scenarios (0.16 for current and 0.15 for future – bearing in mind that the number of excluded sites differs for current (61 sites) vs. future (223 sites) scenarios). This BLM represents an optimised BLM calculated following the methodology suggested by Fisher *et al.* in Ardron *et al.* (2008). Note that this BLM creates for a “hungry algorithm” promotes a larger continuous rather than smaller fragmented conservation network.

15.2.7 Area Requirement Scenarios

Eleven conservation network expansion scenarios were explored using the MARXAN software (Table 15.1.4). The objective of the spatial analyses was to determine (1) where outstanding targets could be achieved; and, (2) the approximate additional area required by the conservation network in order to achieve these targets.

TABLE 15.1.4. A SUMMARY OF THE CONSERVATION NETWORK CURRENT AND FUTURE AREA REQUIREMENTS SCENARIOS BASED ON DIFFERENT TARGET SETS AND ADJACENCY (BLM) CONTSTRAINTS.

<table>
<tr><th>Scenario</th><th>Parameters</th><th>Description</th></tr>
<tr><td>1</td><td>Current, no BLM</td><td>Absolute minimum number of sites required to meet current outstanding targets</td></tr>
<tr><td>2</td><td>Current, BLM</td><td>Minimum number of sites required to (1) meet outstanding targets, and (2) create a contiguous conservation network. This is a more real-world scenario as real-world reserve establishment is rarely spatially efficient relative to meeting targets.</td></tr>
<tr><td>3</td><td>Future1 (species), no BLM</td><td>Absolute minimum number of sites required to meet future outstanding species targets. Targets based on 10% of future distribution of species</td></tr>
<tr><td>4</td><td>Future1 (species), half optimal BLM</td><td rowspan="2">As above but two levels of an adjacency factor (BLM) is introduced to force a more compact reserve scenario</td></tr>
<tr><td>5</td><td>Future1 (species), optimal BLM</td></tr>
<tr><td>6</td><td>Future2 (PP), no BLM</td><td>Minimum number of sites required to maintain existing levels of PP within the current conservation network.</td></tr>
<tr><td>7</td><td>Future2 (PP), half optimal BLM</td><td rowspan="2">As above but two levels of an adjacency factor (BLM) is introduced to force a more compact reserve scenario</td></tr>
<tr><td>8</td><td>Future2 (PP), optimal BLM</td></tr>
<tr><td>9</td><td>Future3 (PP), no BLM</td><td>The minimum number of sites required to represent a given proportion of PP (40%) in the conservation network within each region.</td></tr>
<tr><td>10</td><td>Future3 (PP), half optimal BLM</td><td rowspan="2">As above but two levels of an adjacency factor (BLM) is introduced to force a more compact reserve scenario</td></tr>
<tr><td>11</td><td>Future3 (PP), optimal BLM</td></tr>
</table>

15.3 RESULTS AND DISCUSSION

15.3.1 Gap Assessment and Options for creating a fully representative conservation network

As a proportion of the country Namibia probably has one of the largest conservation network of any country globally. Approximately 45% of the country falls under some form of conservation management (Figure 15.1.3). Only 2% of biodiversity features targeted are not represented within the conservation network at all, and a total of 5% fall short of their target (Figure 15.1.3, Table 15.1.5). We can conclude that currently the Namibian conservation network is representative of the majority of the country's biodiversity.

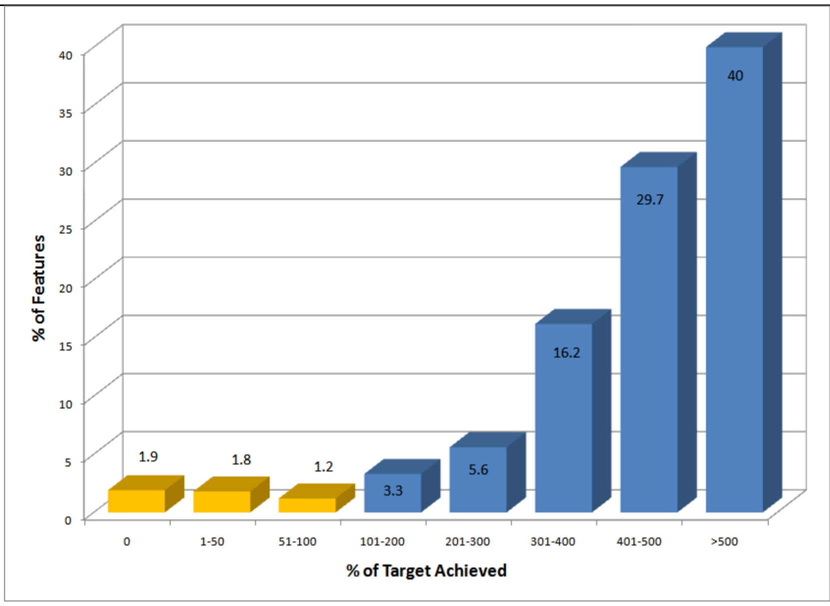


FIGURE 15.1.3. THE PERCENTAGE OF CURRENT TARGETS ACHIEVED BY THE CONSERVATION NETWORK FOR THE 1045 FEATURES USED IN THE GAP ASSESSMENT.

There are some notable gaps in the conservation network

1. In the north of the country targets for the vegetation and land-types of the Cuvelai drainage system cannot be achieved. Based on the land-cover data available this ecosystem has been almost entirely transformed and there is less natural vegetation remaining than the target set (i.e. the ecosystem is greater than 85% transformed). This is the only highly transformed or "critically endangered" landscape in Namibia.
2. The south of the country especially the SE (Nama Karoo and Orange River valley) is the most poorly represented in the conservation network and consequently the area where most outstanding targets are to be met.

TABLE 15.1.5 THE BREAKDOWN PER FEATURE GROUP OF CURRENT TARGETS ACHIEVED BY THE CONSERVATION NETWORK.

	Number of Features		
Feature Group	**Target NOT Achieved**	**Target Achieved**	**Total**
Vegetation Types	27	74	101
Land Types	18	51	69
Species	2	854	856
South Slopes	5	14	19
Total number of features	**52**	**993**	**1045**

Addressing these gaps in the conservation network will require two strategies (**Error! Reference source not found.**):

1. Expansion and consolidation of existing reserves particularly in the north where this strategy can meet all targets.
2. Creation of new reserves particularly in the SE Kalahari, Nama Karoo and eastern Orange River valley regions.

Note that the “selected sites” in Figure 15.4 are attempting to achieve two objectives – (1) reduce the overall boundary length of the conservation network; and, (2) achieve all outstanding targets. Placing less emphasis on creating a contiguous conservation network would mean that far fewer sites would be selected in the north of the country, however, this would have limited impact on areas in the south especially groups of selected sites that are not adjacent to existing protected areas. These sites will still be required as they are selected primarily to meet outstanding targets. The “optimised” conservation network expansion scenario depicted in Figure 15.4 requires adding another 1527 additional sites to the conservation network, roughly 12 million hectares, or expanding the current conservation network by 30% in order to meet current targets for all biodiversity features.

The conservation network currently captures 42.5% of the country’s primary productivity (Table 15.6). At this point the primary productivity (PP) value has not been related to actual carrying capacity although this is possible (e.g. Desmet, 2004; Berliner and Desmet, 2008). What this value does provide though is a future target for the conservation network. One climate adaptation strategy that can be implemented with the conservation network is to maintain the total primary productivity of the conservation network at current levels through conservation network expansion so as to maintain existing animal population sizes. The spatial implications of this conservation network adaptation strategy are explored in Section 15.3.4.

Although the conservation network captures a significant proportion of national PP, an equal proportional representation of each region’s PP is not achieved (Table 15.6). Another CC adaptation strategy might be to ensure that an equal proportion of each regions PP is captured in the conservation network (Future 3 scenario, Table 15.2). The significance of this target on future development options for the conservation network is explored in Section 15.3.4.

TABLE 15.6 THE PROPORTION OF REGIONAL PRIMARY PRODUCTION REPRESENTED IN THE CONSERVATION NETWORK.

Region	Outside	Pas
1 N Namib	11.46	88.54
2 Central Namib	26.86	73.14
3 S Namib	21.23	78.77
4 Nama	87.97	12.03
5 S Kalahari	99	1
6 N Highlands	35.35	64.65
7 Central Shrublands	55.83	44.17
8 Central Kalahari	68.33	31.67
9 N Kalahari	28.53	71.47
10 Karstveld	58.95	41.05
11 W Savanna	56.1	43.9
12 E Savanna	76.7	23.3
Total	**57.5**	**42.5**

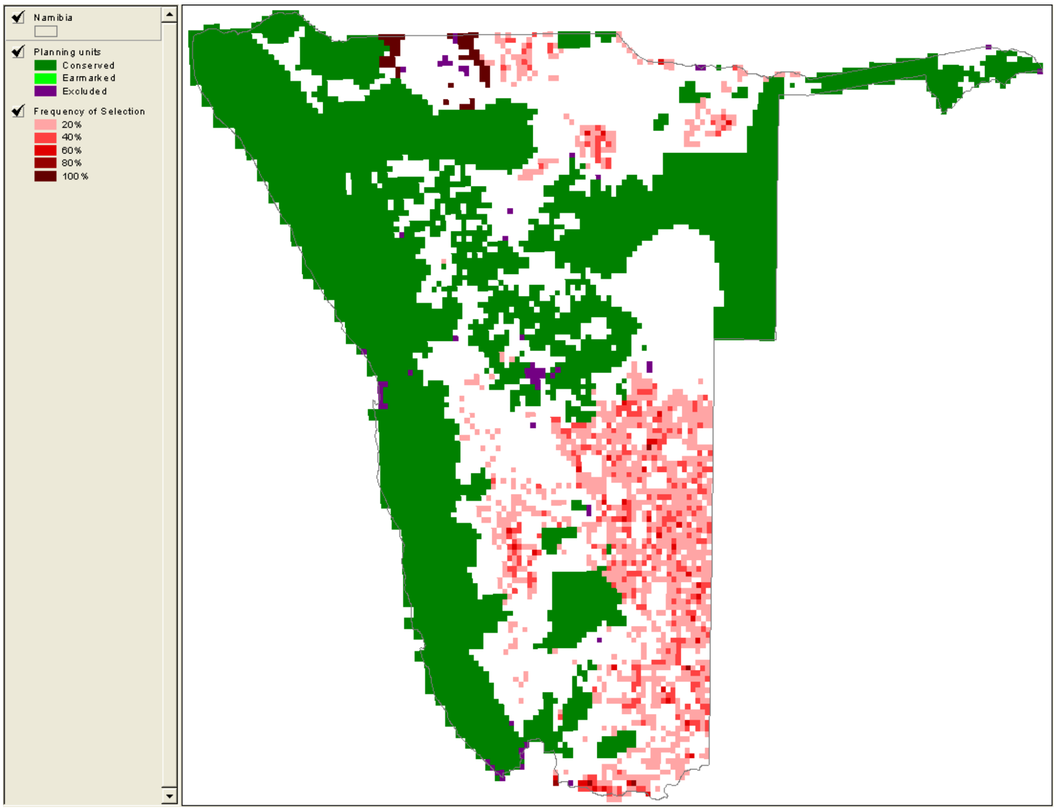


FIGURE 15.5 THE MARXAN SELECTION FREQUENCY OF SITES MEETING ALL BIODIVERSITY TARGETS IN THE PRESENT CLIMATE USING TARGET AND COST ONLY.

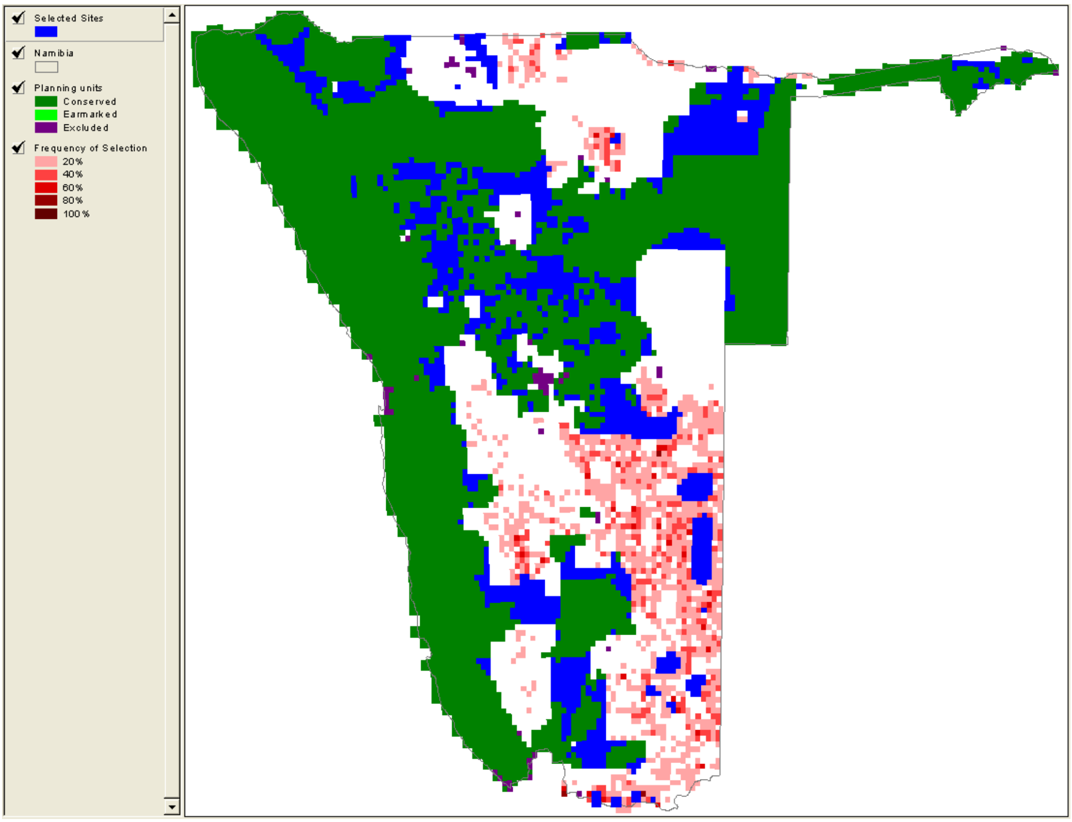


FIGURE 15.5 THE MINIMUM SET OF SITES SELECTED (BLUE) TO MEET ALL BIODIVERSITY TARGETS IN THE PRESENT CLIMATE AS WELL AS MIMINUM COST AND BOUNDARY LENGTH.

15.3.2 Changes in biodiversity distribution under climate change

Primary production

Based on the observed current and future predicted PP the national total PP is predicted to decrease by 4.5%. For the conservation network the decrease is similar and predicted to be 4.4%. In arid areas (<500-600mm rain per annum) PP is directly correlated with the numbers of livestock or game that can be kept on the land. Therefore it is possible to quantify in monetary terms the impact of CC on industries dependent on primary production (stock and game farming, protected areas, fuel wood harvesting) as well as the rural and national economies.

However, change is not equal across the country (Figures 15.6 and 15.7). Summer rainfall areas are expected to increase by as much as 30% especially high-lying areas such as the Kaokoveld (northern escarpment) and central plateau. In contrast, winter and winter/summer ecotone rainfall areas in the south are expected to decrease by as much as 40% particularly in the Central/southern Namib, Succulent Karoo and Nama Karoo. For the conservation network (Table 15.7 and Figure 15.2) this change will have significant impacts on the abilities of protected areas in the Central and Southern Namib and Nama eco-region (change >-15%) whereas elsewhere in the currently summer rainfall areas change is expected to be less severe (-5% to +5%).

TABLE 15.7 THE PERCENTAGE CHANGE IN CONSERVATION NETWORK TOTAL PRIMARY PRODUCTION (RELATIVE UNITS) SUMMARISED PER ECO-REGION.

Region	PP2000	PP2080	% Change
N Namib	8 148 187	7 966 627	-2.2
Central Namib	3 634 438	3 021 807	-16.9
S Namib	3 801 814	3 261 031	-14.2
Nama	2 187 823	1 799 096	-17.8
S Kalahari	82 439	86 176	4.5
N Highlands	6 953 828	7 165 227	3
Central Shrublands	5 031 922	4 908 301	-2.5
Central Kalahari	3 165 280	3 213 166	1.5
N Kalahari	8 112 039	7 552 630	-6.9
Karstveld	3 457 586	3 424 461	-1
W Savanna	2 456 772	2 446 857	-0.4
E Savanna	3 927 390	3 847 292	-2
Total for conservation network	**50 959 518**	**48 692 671**	**-4.4**

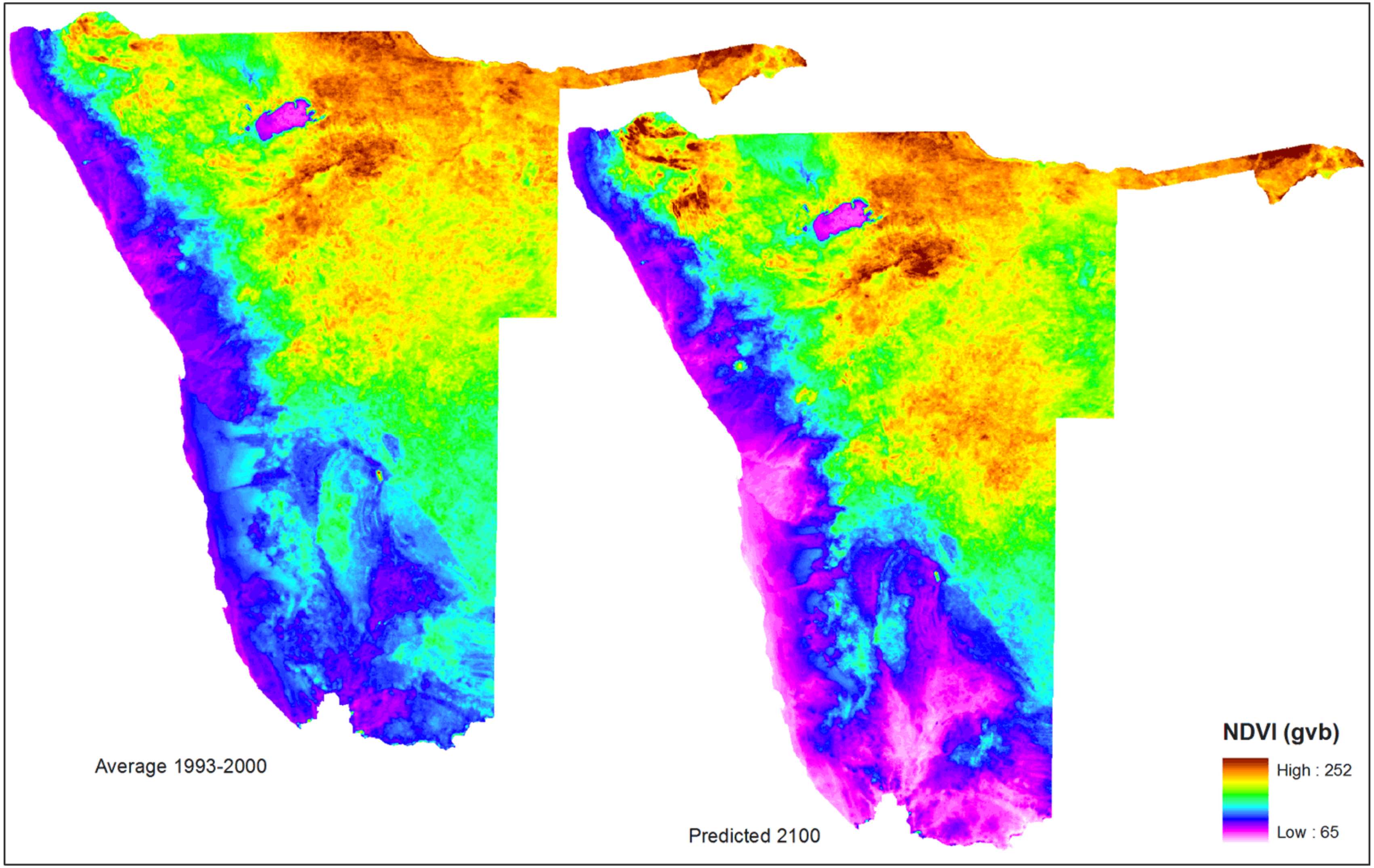


FIGURE 15.6 (FOLLOWING PAGE) PREDICTED CHANGES IN PLANT PRIMARY PRODUCTION (BASED ON MODELLED PP) BETWEEN 2000 AND 2080.

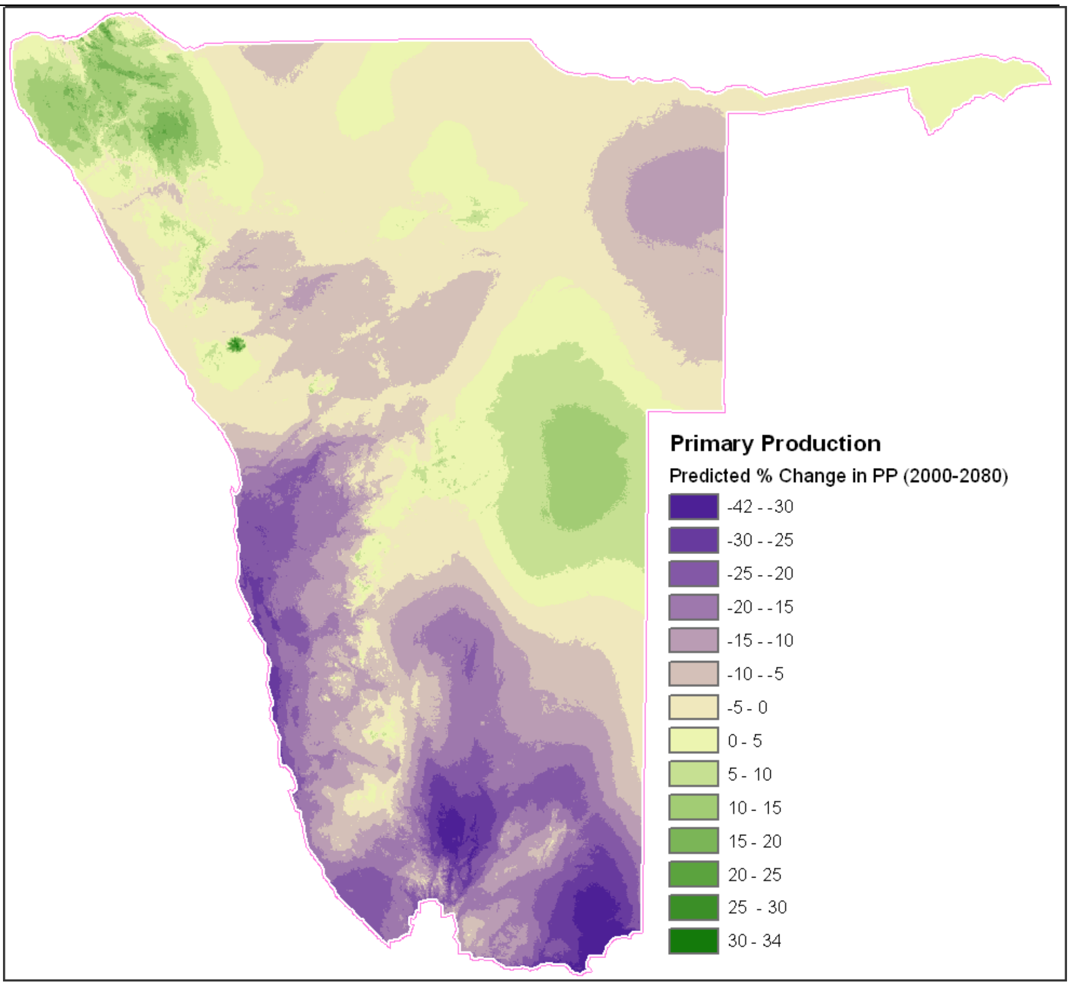


FIGURE 15.7 THE PREDICTED PERCENTAGE CHANGE IN PRIMARY PRODUCTION BETWEEN 2000 AND 2080.

Species range shifts

The outputs from the species distribution modelling are reported in detail in Midgley *et al.* (2005). Below we summarise the results briefly to provide a context for the conservation network analysis.

At the individual species range-level the predictions in terms of changes in overall range size are mixed – 52% of species modelled are expected to have range contractions, 41% range increases and 7% to go extinct from Namibia.

At the vegetation type or ecosystem-level these predicted changes in species ranges show an apparent inverse pattern to what the primary production model is predicting. The areas expected to experience the greatest reduction in PP (south and south west) are predicted to see the greatest increase in total species numbers as well as the lowest proportion of species loss. While this gain in species diversity in areas most affected by CC is perhaps contrary to what might be expected, it may be related to the fact that Namibia is rich in species adapted to warm, dry conditions. With an expansion of such conditions and of low NPP into the future, this rich group of arid-adapted species is modelled to expand their range and migrate into regions that are warming and drying.

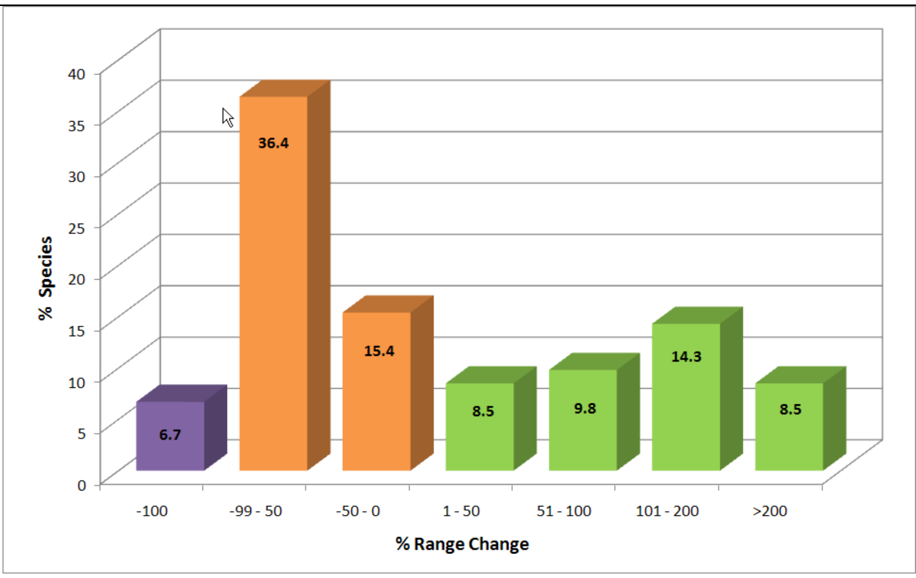


FIGURE 15.8. A SUMMARY OF THE PERCENTAGE CHANGE IN RANGE SIZE FOR THE 857 PLANTS SPECIES MODELLED BY MIDGLEY *ET AL.* (2005). -100% IMPLIES THAT A SPECIES HAS GONE EXTINCT FROM NAMIBIA

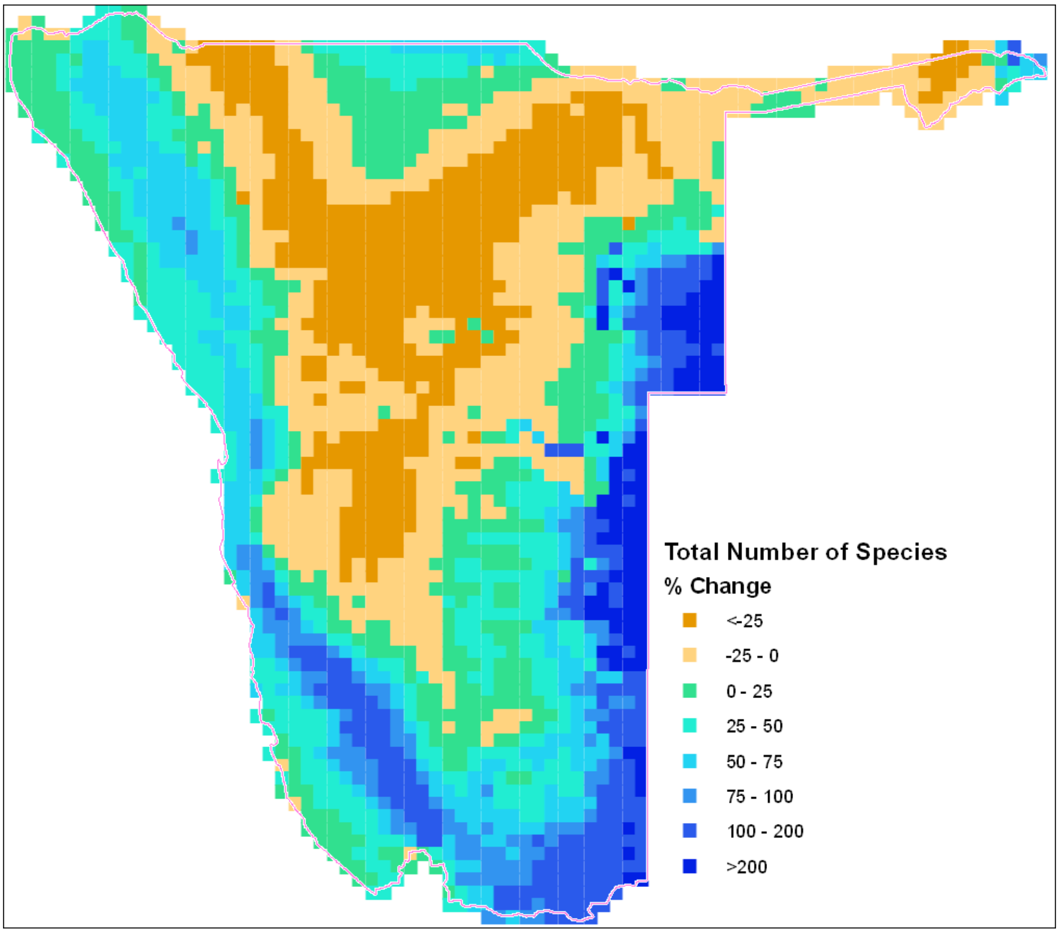


FIGURE 15.9 THE RELATIVE CHANGE IN TOTAL SPECIES NUMBERS ACROSS NAMIBIA 2000-2080 (ORIGINAL DATA FROM MIDELEY *ET AL.* 2005 AND BROENNIMANN *ET AL.* 2006)

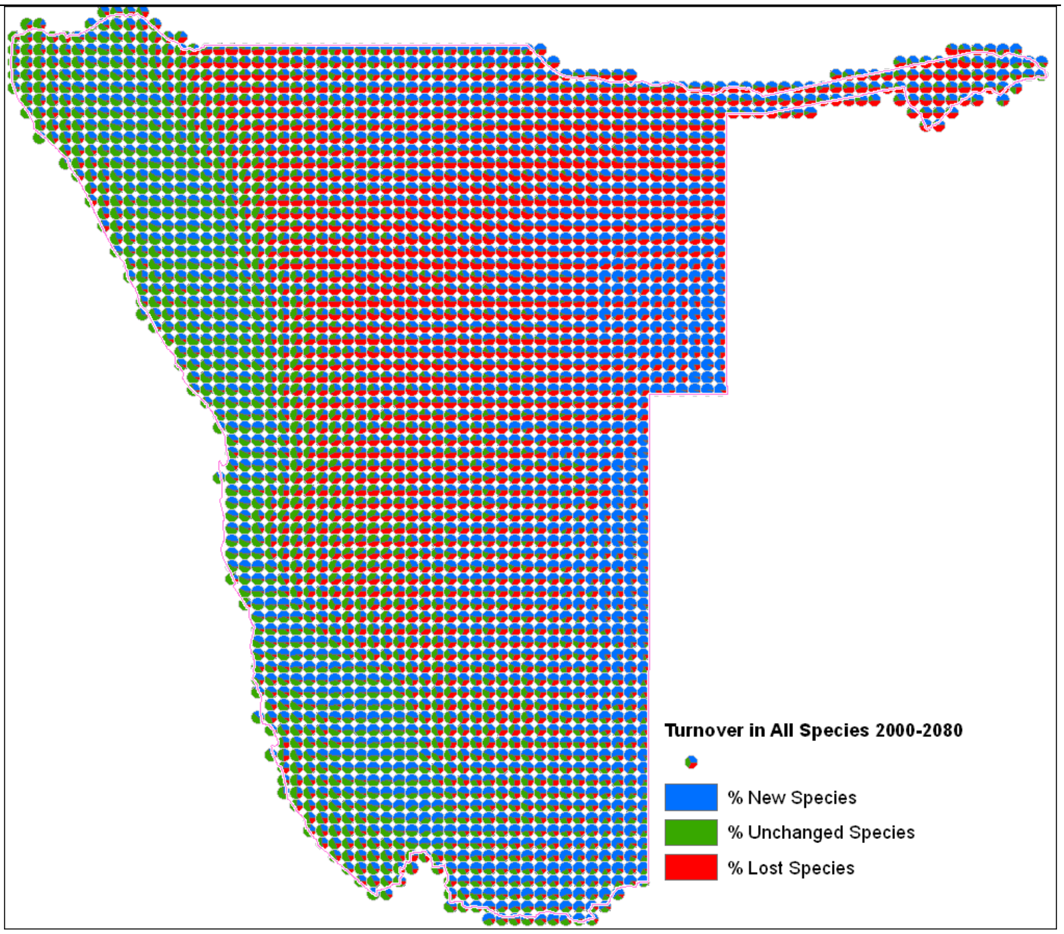


FIGURE 15.10. THE RELATIVE CHANGE IN SPECIES COMPOSITION IN TERMS OF SPECIES GAIN/LOSS FOR THE MODEL PERIOD 2000-2080 (ORIGINAL DATA FROM MIDELEY *ET AL.* 2005 AND BROENNIMANN *ET AL.* 2006).

The assumption made by the species model of rapid migration of these species in response to CC is untested. This raises an important conservation strategy perspective for future consideration – is it possible both practically and cost-wise to assist the migration of desert species to occupy novel ranges? Certainly, effective corridor design at the landscape level is an important first step in such a strategy.

At this stage no analysis in terms of change in vegetation composition (e.g. vegetation structure, palatable species) is attempted due to the limited time available for the project, although with the data available and key inputs from experts this would be possible. Therefore what the impacts of these plant species range changes might be on herbivore communities is unknown.

15.3.3 How well does the current conservation network meet targets for future species distribution?

Deciding on an approach to setting targets to assess how well the current conservation network meets targets for the future distribution of species is not trivial. Should a target be based on the current distribution of species (i.e. the area equivalent of 10% of the current range of each species – Target 1) or relative to the future distribution of species (i.e. the area equivalent of 10% of the future predicted range of each species – Target

2)? This is an important conceptual conservation planning and policy issue that is not resolved here. For the purposes of this analysis the future distribution target (Target 2) is used.

Currently the conservation network achieves 99.7% of targets for species (854 out of 856 species current targets achieved, Table 15.5. The current conservation network is also effective at achieving future targets for plant species - 848 out of a total of 856 (99%) species future targets are achieved by the current conservation network. Mopping-up outstanding future targets, however, is not spatially efficient and would require between a 20-30% expansion of the conservation network to meet targets for all species (Table 15.8). Most of this expansion can be achieved by expanding existing PA's with two notable exceptions – the eastern Orange River Valley and the southern Kalahari/Nama Karoo regions where species priorities are located away from any existing PA.

TABLE 15.8. SUMMARY OF MARXAN MODEL INPUTS AND OUTPUTS FOR THREE PAS EXPANSION OPTION SCENARIOS (3 DEGREES OF COMPACTNESS [BLM]) FOCUSSING ON REPRESENTING 10% OF THE FUTURE PREDICTED RANGE OF EACH PLANT SPECIES (TARGET SCENATIO FUTURE 1, TABLE 15.2). EACH PU IS 18 000HA

	Input			Output			
Scenario	Cost	BLM	Target Scenario	Total Cost	Total PUs	Boundary Length	Required Additional Sites
RUN 3	COST2	ZERO	Future 1	2708360.0	5167	19737454.2	98
RUN 4	COST 2	HALF OPT	Future 1	2831760.0	6205	8550715.6	1136
RUN 5	COST 2	OPT	Future 1	2915960.0	6707	7549047.0	1638

15.3.4 How well does the current conservation network maintain current carrying capacity?

Assessing changes in the PP of the current conservation network is done using two target sets. Future target scenario one assumes the PP of the current conservation network is adequate and looks simply at options for maintaining current PP levels within the context of the future predicted PP (i.e. create a conservation network that maintains the current game carrying capacity, target scenario Future 2, Table 15.2). From Table 15.7 the PP for the conservation network in three regions is predicted to increase whereas those for other regions particularly in the south are predicted to decrease (i.e. 3 out of 12 future PP targets achieved by the current conservation network, Table 15.9).

The current conservation network is not fully representative of Namibia's biodiversity. There are spatial biases with the conservation network being well developed in some regions but underdeveloped or non-existent in other regions. A valid conservation goal would be to ensure that an equal proportion of each regions PP is represented with the conservation network. Currently the conservation network captures 42% of the country's PP (Table 15.6). Therefore a future target might be to ensure that the conservation network captures at least 40% of each eco-region's future PP (Target scenario Future 3, Table 15.2). Using this target set the current conservation network achieves future PP targets for eight of the 12 regions (Table 15.9), one of the regions, the southern Kalahari, has almost no representation within the conservation network.

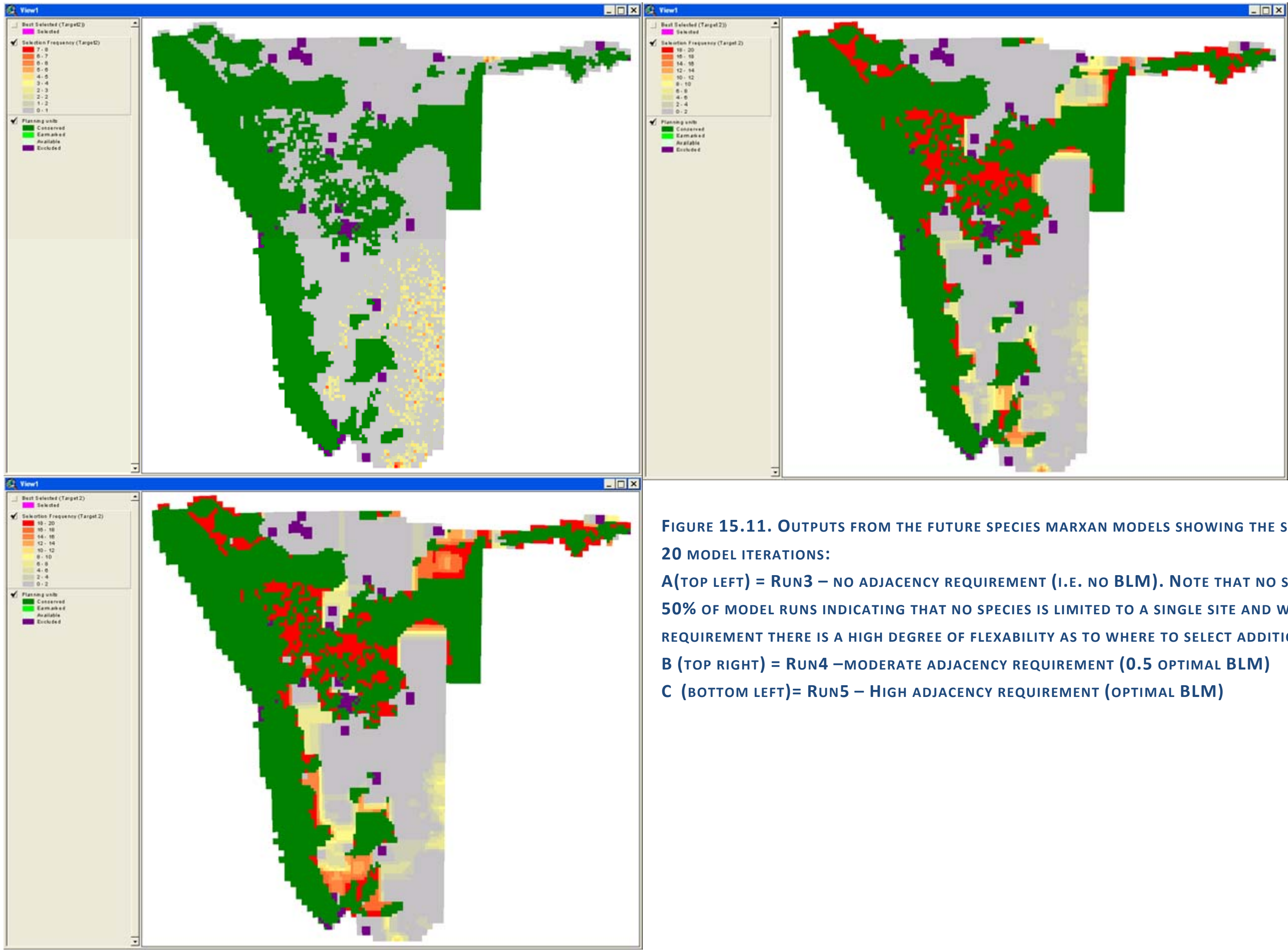


Figure 15.11. Outputs from the future species marxan models showing the selection frequency of sites for 20 model iterations:

A(top left) = Run3 – no adjacency requirement (i.e. no BLM). Note that no site is selected more that 10 or 50% of model runs indicating that no species is limited to a single site and where adjacency is not a requirement there is a high degree of flexability as to where to select additional sites.

B (top right) = Run4 –moderate adjacency requirement (0.5 optimal BLM)

C (bottom left)= Run5 – High adjacency requirement (optimal BLM)

Table 15.9 Summary or percentage of target achieved for the two Primary Production target sets used in the analysis.

Id	Region Name	% Target Achieved	
		Future 2	Future 3
1	N Namib	97.52	226.71
2	Central Namib	83.37	181.15
3	S Namib	85.6	199.42
4	Nama	82.32	34.39
5	S Kalahari	104.61	3.71
6	N Highlands	102.51	179.14
7	Central Shrublands	97.28	138.76
8	Central Kalahari	101.82	85.15
9	N Kalahari	93.34	181.36
10	Karstveld	99.1	116.83
11	W Savanna	99.24	116.92
12	E Savanna	97.99	65.29

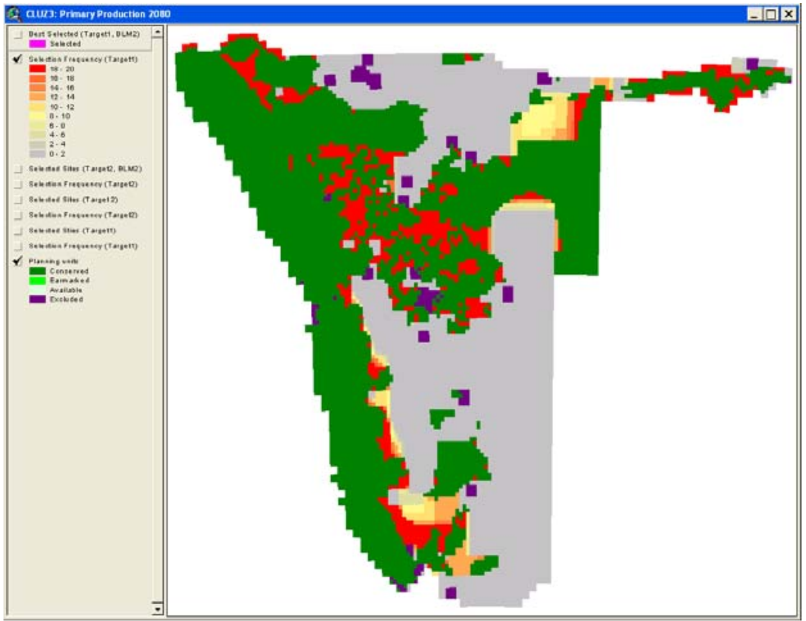
Addressing gaps in the current conservation network to achieve future targets in PP would require between a 35-43% increase in the size of the current conservation network (Table 15.10) Most of this expansion could be achieved by expanding and consolidating existing PAs with notable exceptions in the south of the country particularly the southern Kalahari where there are currently no PAs (Figure 15.12). Consolidation of the conservation network into 3 major bioregional corridors would also contribute significantly to the maintenance of macro-ecological climatic gradient corridors. These corridors are the:

4. North-south escarpment/Namib corridor (existing)
5. West-east Kaokoveld-Caprivi corridor (existing)
6. West-east southern Namib-Kalahari corridor (not existing)

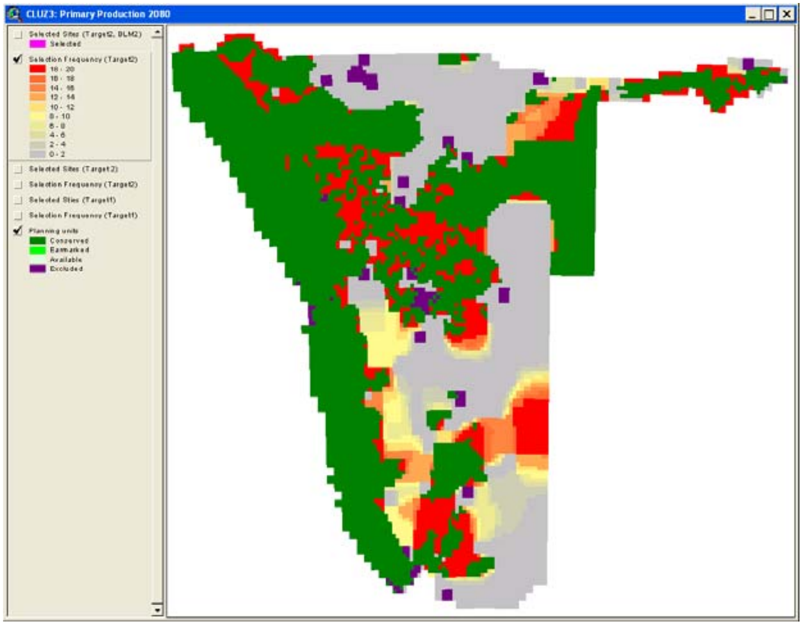
Table 15.10 Summary of MARXAN model inputs and outputs for six conservation network expansion option scenarios (two target sets x 3 degrees of compactness [BLM]) focussing on maintaining current PP (target scenario Future 2) and representing a fixed proportion of future PP in each region (Target scenario Future 3). Each PU is 18 000ha.

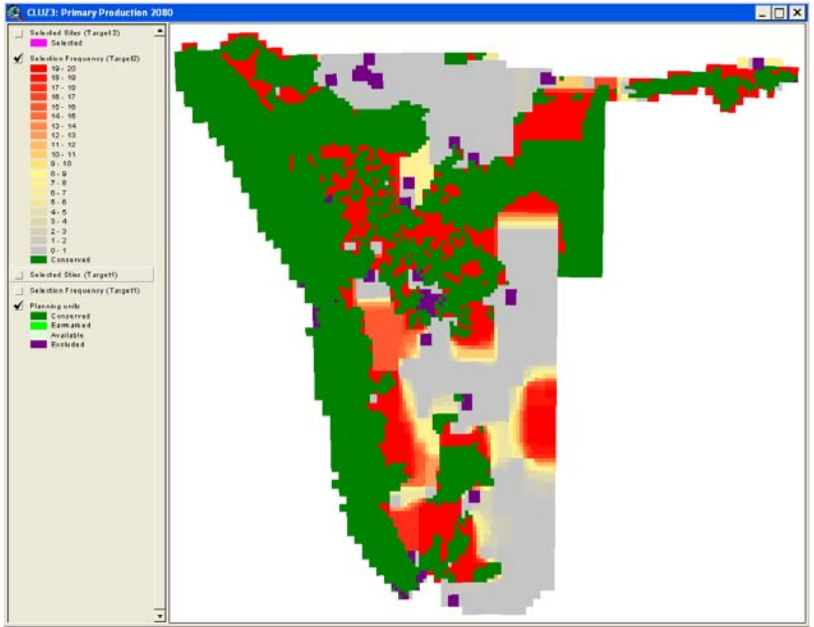
Scenario	Input			Output			
	Cost	BLM	Target Scenario	Total Cost	Total PUs	Boundary Length	Required Additional Sites
RUN9	COST2	ZERO	Future 2	27264.7	5347	21568175.4	278
RUN7	COST2	HALF OPT	Future 2	28399.3	6284	7791131.5	1215
RUN 8	COST2	OPT	Future 2	29396.4	6848	6744097.2	1779
RUN10	COST2	ZERO	Future 3	27935.7	6016	36858526.5	947
RUN6	COST2	HALF OPT	Future 3	29165.8	7016	8043213.2	1947
RUN5	COST2	OPT	Future 3	29976.9	7242	7088248.4	2173

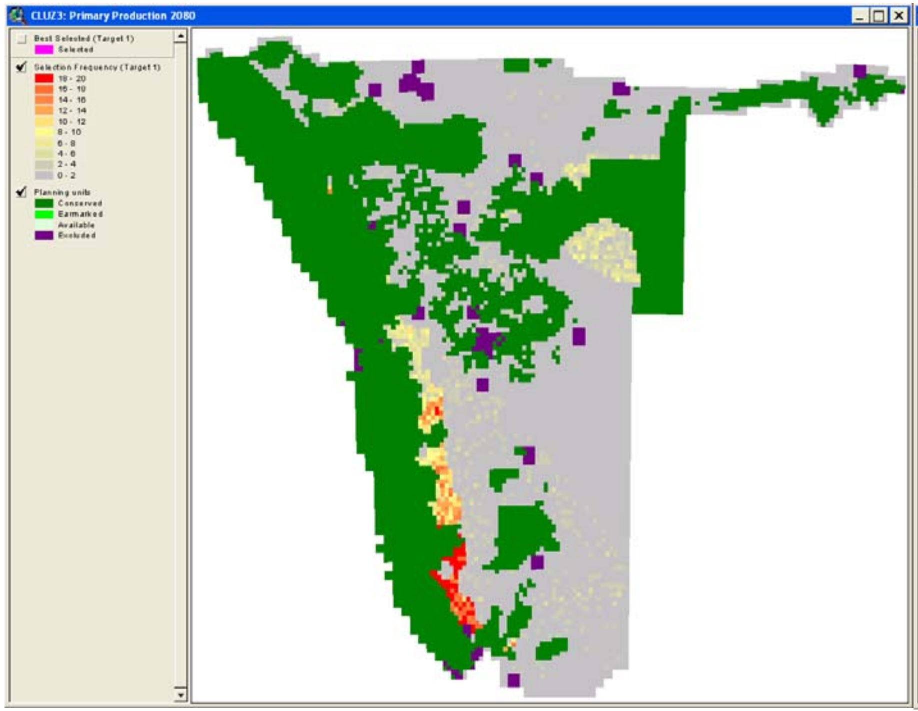
Figure 15.12 (Following Pages) Outputs from the future PP MARXAN models showing the selection frequency of sites for 20 model iterations:
A = Run7: maintain current PP, moderate adjacency requirement
B = Run 8: maintain current PP, high adjacency requirement
C = Run6: Represent equal proportion of future PP, moderate adjacency requirement
D = Run5: Represent equal proportion of future PP, high adjacency requirement
E = Run9: maintain current PP, no adjacency requirement
F = Run10: Represent equal proportion of future PP, no adjacency requirement

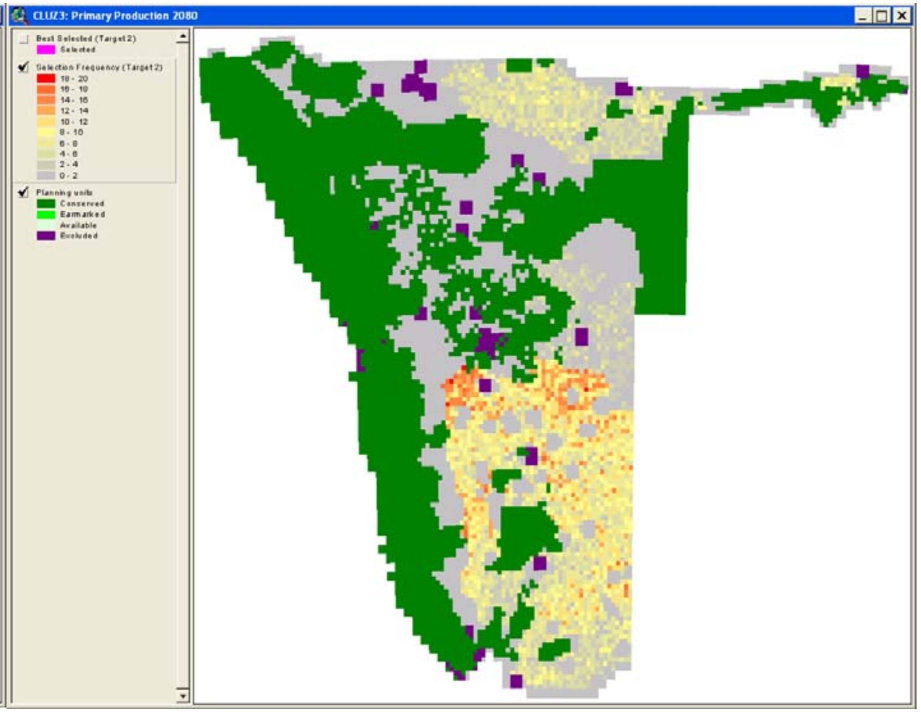

CLUZ3: Primary Production 2080
Conserved
Earmarked
Available
Excluded


CLUZ3: Primary Production 2080
Conserved
Earmarked
Available
Excluded


CLUZ3: Primary Production 2080
Conserved
Earmarked
Available
Excluded


CLUZ3: Primary Production 2080
Conserved
Earmarked
Available
Excluded


CLUZ3: Primary Production 2080
Best Selected (Target 1)
Selected
Selection Frequency (Target 1)
18 - 20
16 - 18
14 - 16
12 - 14
10 - 12
8 - 10
6 - 8
4 - 6
2 - 4
0 - 2
Planning units
Conserved
Earmarked
Available
Excluded


CLUZ3: Primary Production 2080
Best Selected (Target 2)
Selected
Selection Frequency (Target 2)
18 - 20
16 - 18
14 - 16
12 - 14
10 - 12
8 - 10
6 - 8
4 - 6
2 - 4
0 - 2
Planning units
Conserved
Earmarked
Available
Excluded

15.4 Conclusions

Namibia has a well developed conservation network covering nearly 45% of the country that achieves conservation targets for 93% of biodiversity features assessed in this study. This conservation network is well placed to be able to adapt to the challenges of climate change.

Based on the two climate change biodiversity response model datasets used in this study the responses of biodiversity to climate change will not be uniform across the country and will include:

- National total primary production will decrease by 4.5% and 4.4% for the conservation network.
- Changes in primary production will not be equal across the country with primary production increasing in the central interior and north-western sub-regions (Savanna) of the country by as much as 30% and decreasing in southern areas (Succulent and Nama Karoo) by as much as 40%.
- At least 7% of plant species modelled are estimated to shift their distribution range out of Namibia entirely with 52% of species showing range contractions and 41% showing range expansions.
- Changes in species composition are variable with the north and central areas expecting the greatest decrease in total relative species diversity and greatest degree of species change, and the Namib and southern areas expecting the greatest increase in relative species diversity with least degree of species change.

Given the spatial variability in responses adapting the conservation network to these anticipated changes in biodiversity patterns and process will require a variety of strategies. Adaptation strategies could include:

- Building a conservation network that is fully representative of current biodiversity patterns and processes (i.e. meets current targets).
    - The south of the country has been neglected by the conservation network with areas of the eastern Orange River Valley, Nama Karoo and southern Kalahari requiring attention.
    - Focus on including climate change refugia into the conservation network such as mountainous areas that contain habitats (elevation, south-facing slopes and kloofs) that can buffer species locally against macro-scale changes in climate.
    - Use information on the current distribution of biodiversity as well as modelled information on the future distribution of biodiversity to guide conservation network expansion.
- Focus on maintaining biodiversity processes such as:

- Facilitate species movement through building a landscape-level biodiversity corridor network that will allow biodiversity to respond to changing climates. Three large-scale corridors are suggested for Namibia – two already exist to a greater degree (the north-south Namib/Escarpment and east-west Kaokoveld-Caprivi corridors) and one (west-east southern Namib-Kalahari corridor) still needs to be created.
- Promote persistent populations by consolidating areas within the existing conservation network by removing fencing to create larger contiguous management areas that that meet viable animal population size requirements and facilitate species movement in response to seasonal variation.
- Cooperate with neighbouring states when planning and implementing landscape-scale corridors to align conservation management efforts across political boundaries. Biodiversity does not recognise political boundaries.

Using reserve design software to explore conservation network development scenarios aimed at creating a representative conservation network that meets current targets as well as targets for the future distribution of biodiversity whilst maintaining the primary productivity of the conservation network suggest that between a 20-45% increase in the size of the current conservation network will be required to achieve this goal. The wide range in percentage increase is a result of difference target sets being used and different levels of conservation network adjacency or continuity being applied. Given that one of the most important recommendations for conservation network CC adaptation is the creation or maintenance of landscape corridors, and that the Namibian conservation network is relatively fragmented a conservation network expansion figure towards the upper end of our predictions may actually be more realistic. It is important to note that our concept of conservation network here includes all protected categories so we are not recommending that all this expansion should be the work of the state alone but that the private and communal sectors have an important contribution to make.

Multiple target sets (current biodiversity representivity, future biodiversity representivity and primary production) can be achieved simultaneously therefore it is important to include a wide variety of biodiversity features/targets when planning future conservation network expansion. These scenarios do not take into account connectivity within the existing conservation network. It is likely that without adding new areas to the conservation network significant improvements in the landscape ecological functioning of the conservation network could be achieved simply by improving management within the conservation network.
In the short term Namibia’s conservation network expansion strategy should focus on:

1. Creating new protected areas in the Nama Karoo and Orange River Valley to improve the representation of these ecosystems within the conservation network.
2. Focus on improving connectivity within and between existing components of the conservation network.

The change assessment of primary production within the conservation network presented here is fairly simplistic. It is assumed here that there is a direct relationship between PP and animal biomass. This is correct, however, the manner in which PP is proportioned between plant functional types (grass vs. shrub vs. tree) has important implications for the types of animals that are able to utilise this biomass. Changes in dominant plant functional types or vegetation structure would result in changes in animal communities so whilst animal biomass may remain constant or increase in response to increase in total primary production the types of animals able to occupy the veld would change significantly. The data available to this project would allow for more detailed analysis on conservation network carrying capacity and animal community changes in response to climate change.

16APPENDIX IV. SENSITIVITY ANALYSIS FOR ECONOMIC IMPACT ANALYSIS

Woodlands Biome commercial Livestock

Calving Rate	45.0%	50.0%	55.0%	60.0%	**65.0%**	70.0%	75.0%
Net Value Added/Ha	-19.41	-13.50	-7.13	-0.30	**7.00**	14.78	23.05
Percentage					**100%**	211%	329%
Net Cash Income/Ha	-10.76	-6.16	-1.26	3.95	**9.47**	15.31	21.46
Percentage				**42%**	**100%**	162%	227%
Community Income/Ha	6.24	6.24	6.24	6.24	**6.24**	6.24	6.24
Gross Value Added (GNI)	-58,337	730	64,387	132,697	**205,726**	283,540	366,201
Percentage		0%	**31%**	**65%**	**100%**	138%	178%
Net Value Added (NNI)	-194,071	-135,004	-71,348	-3,038	**69,992**	147,805	230,467
Percentage					**100%**	211%	329%

Mortality Rate	15.0%	12.5%	10.0%	7.5%	**5.0%**	2.5%
Net Value Added/Ha	-33.34	-25.97	-16.98	-6.09	**7.00**	22.64
Percentage					**100%**	323%
Net Cash Income/Ha	-16.24	-11.25	-5.39	1.47	**9.47**	18.79
Percentage				**16%**	**100%**	198%
Community Income/Ha	6.24	6.24	6.24	6.24	**6.24**	6.24
Gross Value Added (GNI)	-197,637	-123,948	-34,026	-74,841	**205,726**	362,113
Percentage					**100%**	176%
Net Value Added (NNI)	-333,372	-259,683	-169,760	-60,894	**69,992**	226,379
Percentage					**100%**	323%

Meat Price	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	-11.29	-5.20	0.90	**7.00**	13.10	19.19	25.29
Percentage			13%	**100%**	**187%**	**274%**	361%
Net Cash Income/Ha	-9.77	-3.36	3.06	**9.47**	15.89	22.31	28.72
Percentage			32%	**100%**	**168%**	**236%**	303%
Community Income/Ha	6.24	6.24	6.24	**6.24**	6.24	6.24	6.24
Gross Value Added (GNI)	22,789	837,68	144,747	**205,726**	266,705	327,685	388,664
Percentage	**11%**	41%	70%	**100%**	**130%**	**159%**	189%
Net Value Added (NNI)	-112,945	-51,966	9,016	**69,992**	130,971	191,950	252,929
Percentage			13%	**100%**	**187%**	**274%**	361%

Capital Costs	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	17.01	13.67	10.34	**7.00**	3.66	0.32	-3.01
Percentage	243%	195%	148%	**100%**	**52%**	**5%**	
Net Cash Income/Ha	17.24	14.65	12.06	**9.47**	6.89	4.30	1.71
Percentage	182%	155%	127%	**100%**	**73%**	**45%**	18%
Community Income/Ha	6.24	6.24	6.24	**6.24**	6.24	6.24	6.24
Gross Value Added (GNI)	265,130	245,329	225,528	**205,726**	185,925	166,124	146,323
Percentage	129%	119%	110%	**100%**	**90%**	**81%**	71%
Net Value Added (NNI)	170,116	136,741	103,366	**69,992**	36,617	3,243	-30,132
Percentage	243%	195%	148%	**100%**	**52%**	**5%**	

Savanna Biome Commercial Livestock

Calving Rate	45.0%	50.0%	55.0%	60.0%	**65.0%**	70.0%	75.0%
Net Value Added/Ha	-27.24	-22.24	-16.83	-7.30	**-4.75**	1.95	9.08
Percentage							
Net Cash Income/Ha	-13.83	-9.78	-5.43	2.14	**4.15**	9.40	14.95
Percentage				**52%**	**100%**	227%	360%
Community Income/Ha	6.24	6.24	6.24	6.24	**6.24**	6.24	6.24
Gross Value Added (GNI)	-135,621	-85,689	-31,612	63,708	**89,258**	156,190	227,546
Percentage				**71%**	**100%**	175%	255%
Net Value Added (NNI)	-272,352	-222,421	-168,344	-73,024	**-47,474**	19,458	90,815
Percentage							

Mortality Rate	15.0%	12.5%	10.0%	7.5%	**5.0%**	2.5%	
Net Value Added/Ha	-15.13	-12.65	-10.09	-7.46	**-4.75**	-1.96	
Percentage							
Net Cash Income/Ha	-2.03	-0.53	1.00	2.56	**4.15**	5.77	
Percentage			**24%**	**62%**	**100%**	139%	
Community Income/Ha	6.24	6.24	6.24	6.24	**6.24**	6.24	
Gross Value Added (GNI)	-14,581	10,241	35,816	62,153	**89,258**	117,138	
Percentage		11%	**40%**	**70%**	**100%**	131%	
Net Value Added (NNI)	-151,313	-126,491	-100,915	-74,579	**-47,474**	-19,593	
Percentage							

Meat Price	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	-18.82	-14.13	-9.44	**-4.75**	-0.06	4.64	9.33
Percentage							
Net Cash Income/Ha	-12.55	-6.98	-1.41	**4.15**	9.72	15.28	20.85
Percentage				**100%**	**234%**	**368%**	502%
Community Income/Ha	6.24	6.24	6.24	**6.24**	6.24	6.24	6.24
Gross Value Added (GNI)	-51,493	-4,576	42,341	**89,258**	136,175	183,092	230,009
Percentage			47%	**100%**	**153%**	**205%**	258%
Net Value Added (NNI)	-188,225	-141,308	-94,391	**-47,474**	-557	46,360	93,277
Percentage							

Capital Costs	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	5.43	2.04	-1.35	**-4.75**	-8.14	-11.53	-14.92
Percentage							
Net Cash Income/Ha	12.02	9.40	6.78	**4.15**	1.53	-1.10	-3.72
Percentage	290%	227%	163%	**100%**	**37%**		
Community Income/Ha	6.24	6.24	6.24	**6.24**	6.24	6.24	6.24
Gross Value Added (GNI)	150,011	129,760	109,509	**89,258**	69,007	48,756	28,505
Percentage	168%	145%	123%	**100%**	**77%**	**55%**	32%
Net Value Added (NNI)	54,299	20,374	-13,550	**-47,474**	-81,398	-115,322	-149,246
Percentage							

Karoo Biome Commercial Livestock Keeping

Lambing Rate	100%	110%	120%	125%	**130%**	140%	150%
Net Value Added/Ha	-5.58	-2.10	1.73	3.77	**5.91**	7.13	12.05
Percentage			**29%**	**64%**	**100%**	121%	204%
Net Cash Income/Ha	-2.66	-0.32	2.21	3.54	**4.93**	2.36	5.47
Percentage			**45%**	**72%**	**100%**	48%	111%
Community Income/Ha	4.20	4.20	4.20	4.20	**4.20**	8.50	8.50
Percentage	100%	100%	**100%**	**100%**	**100%**	202%	202%
Gross Value Added (GNI)	-105,300	76,564	276,249	185,018	**494,348**	558,327	815,045
Percentage		15%	**56%**	**37%**	**100%**	113%	165%
Net Value Added (NNI)	-291,402	-109,537	90,148	219,024	**308,247**	372,226	628,944
Percentage			**29%**	**71%**	**100%**	121%	204%

Mortality Rate	38.0%	35.5%	33.0%	30.5%	**28.0%**	25.5%	23.0%
Net Value Added/Ha	-5.91	-3.34	-0.53	2.54	**5.91**	6.25	10.24
Percentage				**43%**	**100%**	106%	173%
Net Cash Income/Ha	-2.65	-0.98	0.84	2.80	**4.93**	1.74	4.21
Percentage			**17%**	**57%**	**100%**	35%	85%
Community Income/Ha	4.20	4.20	4.20	4.20	**4.20**	8.50	8.50
Percentage	100%	100%	**100%**	**100%**	**100%**	202%	202%
Gross Value Added (GNI)	-122,230	11,558	158,306	318,918	**494,348**	512,475	720,619
Percentage		2%	**32%**	**65%**	**100%**	104%	146%
Net Value Added (NNI)	-308,332	-174,543	-27,796	132,816	**308,247**	326,374	534,518
Percentage				**43%**	**100%**	106%	173%

Meat Price	60%	70%	80%	90%	**100%**	110%	120%
Net Value Added/Ha	-5.04	-2.31	0.43	3.17	**5.91**	8.64	11.38
Percentage			7%	54%	**100%**	**146%**	**193%**
Net Cash Income/Ha	-6.59	-3.71	-0.83	2.05	**4.93**	7.81	10.69
Percentage				42%	**100%**	**158%**	**217%**
Community Income/Ha	4.20	4.20	4.20	4.20	**4.20**	4.20	4.20
Gross Value Added (GNI)	-77,223	65,670	208,562	351,455	**494,348**	637,241	780,134
Percentage		13%	42%	71%	**100%**	**129%**	**158%**
Net Value Added (NNI)	-263,325	-120,432	22,461	165,354	**308,247**	451,139	594,032
Percentage			7%	54%	**100%**	**146%**	**193%**

Capital Costs	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	8.57	7.68	6.79	**5.91**	5.02	4.13	3.24
Percentage	145%	130%	115%	**100%**	**85%**	**70%**	55%
Net Cash Income/Ha	6.97	6.29	5.61	**4.93**	4.25	3.57	2.89
Percentage	141%	128%	114%	**100%**	**86%**	**72%**	59%
Community Income/Ha	4.20	4.20	4.20	**4.20**	4.20	4.20	4.20
Gross Value Added (GNI)	577,752	549,951	522,150	**494,348**	466,547	438,745	410,944
Percentage	117%	111%	106%	**100%**	**94%**	**89%**	83%
Net Value Added (NNI)	447,481	401,070	354,658	**308,247**	261,835	215,423	169,012
Percentage	145%	130%	115%	**100%**	**85%**	**70%**	55%

Woodlands Biome Cattle Post

Calving Rate	43.0%	48.0%	53.0%	58.0%	**63.0%**	68.0%	73.0%
Net Value Added/Ha	-2.71	2.74	8.78	15.43	**22.70**	30.62	39.21
		12%	**39%**	**68%**	**100%**	135%	173%
Net Cash Income/Ha	0.88	2.73	4.69	6.75	**8.93**	11.20	13.59
	10%	31%	**53%**	**76%**	**100%**	125%	152%
Community Income/Ha	4.22	4.22	4.22	4.22	**4.22**	4.22	4.22
Gross Value Added (GNI)	5,604	40,496	79,156	121,703	**168,256**	218,935	273,862
	3%	24%	**47%**	**72%**	**100%**	130%	163%
Net Value Added (NNI)	-17,342	17,550	56,210	98,756	**145,309**	195,989	250,916
		12%	**39%**	**68%**	**100%**	135%	173%
Mortality Rate	16.5%	14.0%	11.5%	**9.0%**	6.5%	4.0%	10.5%
Net Value Added/Ha	15.16	17.60	20.11	**22.70**	25.37	28.12	30.94
	67%	78%	**89%**	**100%**	112%	124%	136%
Net Cash Income/Ha	6.67	7.41	8.16	**8.93**	9.70	10.49	11.29
	75%	83%	**91%**	**100%**	109%	117%	126%
Community Income/Ha	4.22	4.22	4.22	**4.22**	4.22	4.22	4.22
Gross Value Added (GNI)	119,993	135,594	151,680	**168,256**	185,325	202,895	220,969
	71%	81%	**90%**	**100%**	110%	121%	131%
Net Value Added (NNI)	97,046	112,648	128,734	**145,309**	162,379	179,948	198,022
	67%	78%	**89%**	**100%**	112%	124%	136%
Meat Price	60%	70%	80%	90%	**100%**	110%	120%
Net Value Added/Ha	3.77	8.50	13.24	17.97	**22.70**	27.44	32.17
	17%	37%	58%	79%	**100%**	**121%**	**142%**
Net Cash Income/Ha	-6.71	-2.80	1.11	5.02	**8.93**	12.84	16.75
			12%	56%	**100%**	**144%**	**188%**
Community Income/Ha	4.22	4.22	4.22	4.22	**4.22**	4.22	4.22
Gross Value Added (GNI)	47,078	77,373	107,667	137,961	**168,256**	198,550	228,844
	28%	46%	64%	82%	**100%**	**118%**	**136%**
Net Value Added (NNI)	24,132	54, 426	84,720	115,015	**145,309**	175,603	205,898
	17%	37%	58%	79%	**100%**	**121%**	**142%**
Capital Costs	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	24.98	24.22	23.46	**22.70**	21.95	21.19	20.43
	110%	107%	103%	**100%**	**97%**	**93%**	90%
Net Cash Income/Ha	10.66	10.08	9.51	**8.93**	8.35	7.777	7.19
	119%	113%	106%	**100%**	**94%**	**87%**	81%
Community Income/Ha	4.22	4.22	4.22	**4.22**	4.22	4.22	4.22
Gross Value Added (GNI)	175,928	173, 371	170, 813	**168,256**	165,698	163,140	160,583
	105%	103%	102%	**100%**	**98%**	**97%**	95%
Net Value Added (NNI)	159,866	155,014	150,161	**145,309**	140,457	135,604	130,752
	110%	107%	103%	**100%**	**97%**	**93%**	90%

Savanna biome cattle post

Calving Rate	43.0%	48.0%	53.0%	58.0%	**63.0%**	68.0%	73.0%
Net Value Added/Ha	-2.37	3.06	9.09	15.72	**22.97**	30.87	39.43
		13%	**40%**	**68%**	**100%**	134%	172%
Net Cash Income/Ha	2.17	4.21	6.36	8.64	**11.03**	13.55	16.17
	20%	38%	**58%**	**78%**	**100%**	123%	147%
Community Income/Ha	4.22	4.22	4.22	4.22	**4.22**	4.22	4.22
Gross Value Added (GNI)	8,044	42,841	81,398	123,834	**170,268**	220,820	275,611
	5%	25%	**48%**	**73%**	**100%**	130%	162%
Net Value Added (NNI)	-15,199	19,598	58,155	100,591	**147,028**	197,578	252,369
		13%	**40%**	**68%**	**100%**	134%	172%

Mortality Rate	16.5%	14.0%	11.5%	**9.0%**	6.5%	4.0%	1.5%
Net Value Added/Ha	15.45	17.88	20.39	**22.97**	25.63	28.37	31.19
	67%	78%	**89%**	**100%**	112%	124%	136%
Net Cash Income/Ha	8.55	9.36	10.19	**11.03**	11.89	12.76	13.64
	78%	85%	**92%**	**100%**	108%	116%	124%
Community Income/Ha	4.22	4.22	4.22	**4.22**	4.22	4.22	4.22
Gross Value Added (GNI)	122,128	137,690	153,735	**170,268**	187,298	204,820	222,849
	72%	81%	**90%**	**100%**	110%	120%	131%
Net Value Added (NNI)	98,886	114,447	130,492	**147,025**	164,052	181,577	199,606
	67%	78%	**89%**	**100%**	112%	124%	136%

Meat Price	60%	70%	80%	90%	**100%**	110%	120%
Net Value Added/Ha	3.98	8.75	13.47	18.22	**22.97**	21.72	32.47
	17%	38%	59%	79%	**100%**	**95%**	**141%**
Net Cash Income/Ha	-5.24	-1.18	2.89	6.96	**11.03**	15.10	19.17
			26%	63%	**100%**	**137%**	**174%**
Community Income/Ha	4.22	4.22	4.22	4.22	**4.22**	4.22	4.22
Gross Value Added (GNI)	48,695	79,088	109,482	116,632	**170,268**	200,661	231,054
	29%	46%	64%	68%	**100%**	**118%**	**136%**
Net Value Added (NNI)	25,453	55,846	86,239	139,857	**147,025**	177,418	207,811
	17%	38%	59%	95%	**100%**	**121%**	**141%**

Capital Costs	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	25.28	24.51	23.74	**22.97**	22.20	21.43	20.66
	110%	107%	103%	**100%**	**97%**	**93%**	90%
Net Cash Income/Ha	12.77	12.19	11.61	**11.03**	10.45	9.87	9.29
	116%	111%	105%	**100%**	**95%**	**89%**	84%
Community Income/Ha	4.22	4.22	4.22	**4.22**	4.22	4.22	4.22
Gross Value Added (GNI)	178,069	175,469	172,868	**170,268**	167,688	165,067	162,467
	105%	103%	102%	**100%**	**98%**	**97%**	95%
Net Value Added (NNI)	161,799	156,874	151,950	**147,025**	142,100	137,176	132,251
	110%	107%	103%	**100%**	**97%**	**93%**	90%

Woodlands Biome Traditional Livestock Keeping

Calving Rate	40.0%	45.0%	50.0%	55.0%	**60.0%**	65.0%	70.0%
Net Value Added/Ha	-9.95	1.88	14.83	28.94	**44.24**	60.75	78.51
Percentage	-22%	4%	**34%**	**65%**	**100%**	137%	177%
Net Cash Income/Ha	47.42	57.57	68.32	79.68	**91.66**	104.26	117.49
Percentage	52%	63%	**75%**	**87%**	**100%**	114%	128%
Community Income/Ha	86.42	96.57	107.32	118.68	**130.66**	143.26	156.49
Gross Value Added (GNI)	69	2,199	4,530	7,070	**9,823**	12,795	15,992
Percentage	1%	22%	**46%**	**72%**	**100%**	130%	163%
Net Value Added (NNI)	-1,791	339	2,670	5,210	**7,963**	10,935	14,132
Percentage	-22%	4%	**34%**	**65%**	**100%**	137%	177%

Mortality Rate	25.5%	23.0%	20.5%	**18.0%**	15.5%	13.0%	10.5%
Net Value Added/Ha	27.51	32.93	38.5	**44.24**	50.14	56.2	62.43
Percentage	62%	**74%**	**87%**	**100%**	113%	127%	141%
Net Cash Income/Ha	78.55	82.83	87.2	**91.66**	96.19	100.81	105.52
Percentage	86%	**90%**	**95%**	**100%**	105%	110%	115%
Community Income/Ha	117.55	121.83	126.2	**130.66**	135.19	139.81	144.52
Gross Value Added (GNI)	6,813	7,787	8,790	**9,823**	10,884	11,976	13,097
Percentage	69%	**79%**	**89%**	**100%**	111%	122%	133%
Net Value Added (NNI)	4953	5,927	6,930	**7,963**	9,024	10,116	11,237
Percentage	62%	**74%**	**87%**	**100%**	113%	127%	141%

Meat Price	60%	70%	80%	90%	**100%**	110%	120%
Net Value Added/Ha	34.47	36.91	39.35	41.79	**44.24**	46.68	49.12
Percentage	**78%**	83%	89%	94%	**100%**	**106%**	**111%**
Net Cash Income/Ha	72.27	77.12	81.96	86.81	**91.96**	96.5	101.35
Percentage	**79%**	84%	89%	94%	**100%**	**105%**	**110%**
Community Income/Ha	111.27	116.12	120.96	125.81	**130.66**	135.5	140.35
Gross Value Added (GNI)	8064	8,504	8,943	9,383	**9,823**	10,263	10,702
Percentage	**82%**	87%	91%	96%	**100%**	**104%**	**109%**
Net Value Added (NNI)	6,204	6,643	7,083	7,523	**7,963**	8,402	8,842
Percentage	**78%**	83%	89%	94%	**100%**	**106%**	**111%**

Capital Costs	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	52.34	49.64	46.94	**44.24**	41.54	38.84	36.13
Percentage	118%	112%	106%	**100%**	**94%**	**88%**	82%
Net Cash Income/Ha	95.83	94.44	93.05	**91.66**	90.27	88.88	87.49
Percentage	105%	103%	102%	**100%**	**98%**	**97%**	95%
Community Income/Ha	134.83	133.44	132.05	**130.66**	129.27	127.88	126.49
Gross Value Added (GNI)	10,723	10,423	10,123	**9,823**	9,523	9,222	8,922
Percentage	109%	106%	103%	**100%**	**97%**	**94%**	91%
Net Value Added (NNI)	9,421	8,935	8,449	**7,963**	7,477	6,990	6,504
Percentage	118%	112%	106%	**100%**	**94%**	**88%**	82%

Savanna Biome Traditional Livestock Keeping

Calving Rate	40.0%	45.0%	50.0%	55.0%	**60.0%**	65.0%	70.0%
Percentage	67%	75%	**83%**	**92%**	**100%**	108%	117%
Net Value Added/Ha	-19.24	-9.64	0.95	12.55	**25.20**	38.92	53.75
Percentage	-76%	-38%	**4%**	**50%**	**100%**	154%	213%
Net Cash Income/Ha	30.01	37.68	45.81	54.39	**63.43**	72.94	82.92
Percentage	47%	59%	**72%**	**86%**	**100%**	115%	131%
Community Income/Ha	69.01	76.68	84.81	93.39	**102.43**	111.94	121.92
Gross Value Added (GNI)	-2,241	-513	1,392	3,481	**5,757**	8,227	10,896
Percentage	-39%	-9%	**24%**	**60%**	**100%**	143%	189%
Net Value Added (NNI)	-3,462	-1,735	171	2,259	**4,536**	7,006	9,674
Percentage	-76%	-38%	**4%**	**50%**	**100%**	154%	213%

Mortality Rate	25.5%	23.0%	20.5%	**18.0%**	15.5%	13.0%	10.5%
Net Value Added/Ha	11.37	15.84	20.45	**25.2**	30.09	35.13	40.32
Percentage	45%	**63%**	**81%**	**100%**	119%	139%	160%
Net Cash Income/Ha	53.53	56.77	60.07	**63.43**	66.86	70.34	73.89
Percentage	84%	**90%**	**95%**	**100%**	105%	111%	116%
Community Income/Ha	92.53	95.77	99.07	**102.43**	105.86	109.34	112.89
Gross Value Added (GNI)	3,269	4,073	4,902	**5,757**	6,638	7,545	8,479
Percentage	57%	**71%**	**85%**	**100%**	115%	131%	147%
Net Value Added (NNI)	2,047	2,852	3,681	**4,536**	5,417	6,324	7,257
Percentage	45%	**63%**	**81%**	**100%**	119%	139%	160%

Meat Price	60%	70%	80%	90%	**100%**	110%	120%
Net Value Added/Ha	15.43	17.87	20.31	22.76	**25.2**	27.64	30.09
Percentage	**61%**	71%	**81%**	**90%**	**100%**	**110%**	**119%**
Net Cash Income/Ha	44.05	48.89	53.74	58.59	**63.43**	68.28	73.13
Percentage	**69%**	77%	**85%**	**92%**	**100%**	**108%**	**115%**
Community Income/Ha	83.05	87.89	92.74	97.59	**102.43**	107.28	112.13
Gross Value Added (GNI)	3,998	4,438	4,878	5,318	**5,757**	6,197	6,637
Percentage	**69%**	77%	**85%**	**92%**	**100%**	**108%**	**1%**
Net Value Added (NNI)	2,777	3,217	3,657	4,096	**4,536**	4,976	5,416
Percentage	**61%**	71%	**81%**	**90%**	**100%**	**110%**	**119%**

Capital Costs	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	30.4	28.66	26.93	**25.2**	23.47	21.74	20
Percentage	121%	114%	107%	**100%**	**93%**	**86%**	79%
Net Cash Income/Ha	66.5	65.48	64.46	**63.43**	62.41	61.39	60.36
Percentage	105%	103%	102%	**100%**	**98%**	**97%**	95%
Community Income/Ha	105.5	104.48	103.46	**102.43**	101.41	100.39	99.36
Gross Value Added (GNI)	6,326	6,137	5,947	**5,757**	5,568	5,378	5,189
Percentage	110%	107%	103%	**100%**	**97%**	**93%**	90%
Net Value Added (NNI)	5,471	5,160	4,848	**4,536**	4,224	3,913	3,601
Percentage	121%	114%	107%	**100%**	**93%**	**86%**	79%

Karoo biome -Traditional Livestock Keeping

Lambing Rate	60%	65%	70%	75%	80%	85%	**90%**
Net Value Added/Ha	-2.45	-1.82	-1.17	-0.50	0.19	0.91	**1.66**
Percentage					**11%**	**55%**	**100%**
Net Cash Income/Ha	0.08	0.29	0.50	0.73	0.96	1.19	**1.43**
Percentage	6%	20%	35%	51%	**67%**	**83%**	**100%**
Community Income/Ha	1.47	1.68	1.89	2.12	2.35	2.58	**2.82**
Gross Value Added (GNI)	-3,057	-1,602	-93	1,472	3,095	4,767	**6,498**
Percentage				23%	**48%**	**73%**	**100%**
Net Value Added (NNI)	-5,698	-4,243	-2,734	-1,169	451	2,126	**3,857**
Percentage					**12%**	**55%**	**100%**
Mortality Rate	47.5%	45.0%	42.5%	**40.0%**	37.5%	35.0%	32.5%
Net Value Added/Ha	-0.12	0.45	1.04	**1.66**	1.38	1.77	2.19
Percentage		**27%**	**63%**	**100%**	83%	107%	132%
Net Cash Income/Ha	0.84	1.03	1.23	**1.43**	0.99	1.11	1.25
Percentage	59%	**72%**	**86%**	**100%**	69%	78%	87%
Community Income/Ha	2.23	2.42	2.62	**2.82**	1.82	1.95	2.08
Gross Value Added (GNI)	2,350	3,680	5,063	**6,498**	7,988	9,533	11,132
Percentage	36%	**57%**	**78%**	**100%**	123%	147%	171%
Net Value Added (NNI)	-291	1,039	2,421	**3,857**	5,347	6,891	8,491
Percentage		**27%**	**63%**	**100%**	139%	179%	220%
Meat Price	60%	70%	80%	90%	**100%**	110%	120%
Net Value Added/Ha	-0.61	0.04	0.52	1.09	**1.66**	2.22	2.79
Percentage		2%	31%	66%	**100%**	**134%**	**168%**
Net Cash Income/Ha	-1.20	-0.54	0.12	0.78	**1.43**	2.09	2.75
Percentage			8%	55%	**100%**	**146%**	**192%**
Community Income/Ha	0.19	0.85	1.51	2.17	**2.82**	3.48	4.14
Gross Value Added (GNI)	1,217	2,537	3,858	5,178	**6,498**	7,819	9,139
Percentage	**19%**	39%	59%	80%	**100%**	**120%**	**141%**
Net Value Added (NNI)	-1,424	-104	1,217	2,537	**3,857**	5,178	6,498
Percentage			32%	66%	**100%**	**134%**	**168%**
Capital Costs	70%	80%	90%	**100%**	110%	120%	130%
Net Value Added/Ha	2.34	2.11	1.88	**1.66**	1.43	1.20	0.97
Percentage	141%	127%	113%	**100%**	**86%**	**72%**	58%
Net Cash Income/Ha	1.96	1.78	1.61	**1.43**	1.26	1.08	0.91
Percentage	137%	124%	113%	**100%**	**88%**	**76%**	64%
Community Income/Ha	3.35	3.17	3.00	**2.82**	2.65	2.47	2.30
Gross Value Added (GNI)	7,301	7,034	6,766	**6,498**	6,231	5,963	5,696
Percentage	112%	108%	104%	**100%**	**96%**	**92%**	88%
Net Value Added (NNI)	5,453	4,921	4,389	**3,857**	3,326	2,794	2,262
Percentage	141%	128%	114%	**100%**	**86%**	**72%**	59%

Woodlands biome Tourism Wildlife Viewing

Occupancy Rates	27.5%	37.5%	47.5%	**57.5%**	67.5%	77.5%
Net Value Added/Ha	378.23	397.81	417.40	**436.99**	456.58	476.16
Percentage	87%	**91%**	**96%**	**100%**	104%	109%
Net Cash Income/Ha	245.57	262.89	280.22	**297.54**	314.87	332.19
Percentage	83%	**88%**	**94%**	**100%**	106%	112%
Community Income/Ha	43.50	43.50	43.50	**43.50**	43.50	43.50
Gross Value Added (GNI)	6,120,152	6,402,238	6,684,324	**6,966,410**	7,248,496	7,530,582
Percentage	88%	**92%**	**96%**	**100%**	104%	108%
Net Value Added (NNI)	5,446,448	5,728,534	6,010,620	**6,292,706**	6,574,792	6,856,878
Percentage	87%	**91%**	**96%**	**100%**	104%	109%

Tariffs	70.0%	80.0%	90.0%	**100.0%**	110.0%	120.0%
Net Value Added/Ha	252.10	313.73	375.36	**436.99**	498.62	560.26
Percentage	58%	72%	86%	**100%**	**114%**	**128%**
Net Cash Income/Ha	149.61	198.92	248.23	**297.54**	346.85	396.16
Percentage	50%	67%	83%	**100%**	**117%**	**133%**
Community Income/Ha	43.50	43.50	43.50	**43.50**	43.50	43.50
Gross Value Added (GNI)	4,303,954	5,191,439	6,078,925	**6,966,410**	7,853,896	8,741,381
Percentage	62%	75%	87%	**100%**	**113%**	**125%**
Net Value Added (NNI)	3,630,250	4,517,735	5,405,221	**6,292,706**	7,180,192	8,067,677
Percentage	58%	72%	86%	**100%**	**114%**	**128%**

Capital Costs	70%	80%	90%	**100%**	110%	120%
Net Value Added/Ha	475.73	462.82	449.91	**436.99**	424.08	411.17
Percentage	109%	106%	103%	**100%**	**97%**	**94%**
Net Cash Income/Ha	328.02	317.86	307.7	**297.54**	287.38	277.22
Percentage	110%	107%	103%	**100%**	**97%**	**93%**
Community Income/Ha	43.5	43.5	43.5	**43.50**	43.5	43.5
Gross Value Added (GNI)	7,322,085	7,203,527	7,084,968	**6,966,410**	6,847,852	6,729,294
Percentage	105%	103%	102%	**100%**	**98%**	**97%**
Net Value Added (NNI)	6,850,492	6,664,563	6,478,635	**6,292,706**	6,106,777	5,920,849
Percentage	109%	106%	103%	**100%**	**97%**	**94%**

Savanna biome Tourism Wildlife viewing

Occupancy Rates	23%	33%	43%	**53%**	63%	73%
Net Value Added/Ha	48.31	150.46	252.60	**354.72**	456.88	559.02
Percentage	14%	**42%**	**71%**	**100%**	129%	158%
Net Cash Income/Ha	-53.00	8.06	69.12	**130.17**	191.24	252.30
Percentage	-41%	**6%**	**53%**	**100%**	147%	194%
Community Income/Ha	55.08	55.08	55.08	**55.08**	55.08	55.08
Gross Value Added (GNI)	2,126,964	4,884,789	7,642,614	**10,399,854**	13,335,779	15,916,088
Percentage	20%	**47%**	**73%**	**100%**	128%	153%
Net Value Added (NNI)	1,304,480	4,062,304	6,820,129	**9,577,370**	12,335,779	15,093,604
Percentage	14%	**42%**	**71%**	**100%**	129%	158%

Tariffs	70.0%	80.0%	90.0%	**100.0%**	110.0%	120.0%
Net Value Added/Ha	184.29	241.1	297.91	**354.72**	411.53	468.34
Percentage	52%	68%	84%	**100%**	**116%**	**132%**
Net Cash Income/Ha	28.28	62.24	96.2	**130.17**	164.13	198.09
Percentage	22%	48%	74%	**100%**	**126%**	**152%**
Community Income/Ha	55.08	55.08	55.08	**55.08**	55.08	55.08
Gross Value Added (GNI)	5,798,189	7,332,077	8,865,966	**10,399,854**	11,933,743	13,476,310
Percentage	56%	71%	85%	**100%**	**115%**	**130%**
Net Value Added (NNI)	4,975,704	6,595,930	8,043,481	**9,577,370**	11,111,285	12,645,147
Percentage	52%	69%	84%	**100%**	**116%**	**132%**

Capital Costs	70%	80%	90%	**100%**	110%	120%
Net Value Added/Ha	389.73	378.06	366.39	**354.72**	343.05	331.37
Percentage	110%	107%	103%	**100%**	**97%**	**93%**
Net Cash Income/Ha	150.61	143.8	136.98	**130.17**	123.35	116.53
Percentage	116%	110%	105%	**100%**	**95%**	**90%**
Community Income/Ha	55.8	55.8	55.08	**55.08**	55.08	55.08
Gross Value Added (GNI)	11,097,944	10,865,247	10,632,551	**10,399,854**	10,167,158	9,934,461
Percentage	107%	104%	102%	**100%**	**98%**	**96%**
Net Value Added (NNI)	10,522,807	10,207,661	9,892,515	**9,577,370**	9,262,224	8,947,078
Percentage	110%	107%	103%	**100%**	**97%**	**93%**

Karoo biome - Tourism Wildlife Viewing

Occupancy Rate	33%	43%	53%	**63%**	73%	83%
Net Value Added/Ha	16.98	43.00	69.02	**95.04**	121.06	147.08
Percentage	18%	**45%**	**73%**	**100%**	127%	155%
Net Cash Income/Ha	-1.83	19.63	41.08	**62.53**	83.99	105.44
Percentage	-3%	**31%**	**66%**	**100%**	134%	169%
Community Income/Ha	29.63	29.63	29.63	**29.63**	29.63	29.63
Gross Value Added (GNI)	2,719,382	4,983,093	7,246,803	**9,510,514**	11,774,224	14,037,935
Percentage	29%	**52%**	**76%**	**100%**	124%	148%
Net Value Added (NNI)	1,477,258	3,740,969	6,004,679	**8,268,390**	10,532,100	12,795,811
Percentage	18%	**45%**	**73%**	**100%**	127%	155%

Tariffs	70.0%	80.0%	90.0%	**100.0%**	110.0%	120.0%
Net Value Added/Ha	54.33	67.90	81.47	**95.04**	108.61	122.18
Percentage	57%	71%	86%	**100%**	**114%**	**129%**
Net Cash Income/Ha	28.97	40.16	51.35	**62.53**	73.72	84.91
Percentage	46%	64%	82%	**100%**	**118%**	**136%**
Community Income/Ha	29.63	29.63	29.63	**29.63**	29.63	29.63
Gross Value Added (GNI)	5,968,845	7,149,402	7,087,834	**9,510,514**	10,691,070	11,871,626
Percentage	63%	75%	75%	**100%**	**112%**	**125%**
Net Value Added (NNI)	4,726,721	5,907,277	8329,950	**8,268,390**	9,448,946	9,448,946
Percentage	57%	71%	101%	**100%**	**114%**	**114%**

Capital Costs	70%	80%	90%	**100%**	110%	120%
Net Value Added/Ha	111.61	106.00	100.56	**95.04**	89.51	83.99
Percentage	117%	112%	106%	**100%**	**94%**	**88%**
Net Cash Income/Ha	72.63	69.26	65.90	**62.53**	59.17	55.80
Percentage	116%	111%	105%	**100%**	**95%**	**89%**
Community Income/Ha	29.63	29.63	29.63	**29.63**	29.63	29.63
Gross Value Added (GNI)	10,579,172	10,222,952	9,866,733	**9,510,514**	9,154,294	8,798,075
Percentage	111%	107%	104%	**100%**	**96%**	**93%**
Net Value Added (NNI)	9,710,315	9,229,673	8,749,031	**8,268,390**	7,787,748	7,307,106
Percentage	117%	112%	106%	**100%**	**94%**	**88%**

17 REFERENCES

Alemaw, B.F. & Chaoka, T.R. 2006. The 1950-1998 Warm Enso Events and Regional Implications to River Flow Variability in Southern Africa. *Water SA* **32**:459-464.

Ardron, J.A., Possingham, H.P. & Klein, C.J. (Eds). 2008. MARXAN Good Practices Handbook. External review version. Vancouver, BC, Canada, Pacific Marine Analysis and Research Association, www.pacmara.org.

Ball, I.R. & Possingham, H.P. 2000. MARXAN (V1.8.2): Marine Reserve Design Using Spatially Explicit Annealing, a Manual. The Ecology Centre, University of Queensland. Brisbane, Australia.

Bakun, A. 1990. Global climate change and intensification of global upwelling. *Science* **247**:198-201.

Bapna, M., McGray, H., Mock, G., Mlthey, L. 2009. *Enabling adaptation: priorities for supporting the rual poor in a changing climate*. World Resources Institute Issue Brief. Washington DC.

Barnard, P. (Ed.) 1998. *Biological Diversity in Namibia: A country study*. Namibia National Biodiversity Task Force, Windhoek and UNEP, Nairobi. 332pp.

Barnard, P., Brown, C.J., Jarvis, A.M. & Robertson, A. 1998. Extending the Namibian protected area network to safeguard hotspots of endemism and diversity. *Biodiversity and Conservation* **7:**531-547.

Barnes, J.I. 1995b. *The value of non-agricultural land use in some Namibian communal areas: a data base for planning.* DEA Research Discussion Paper No. 6. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Namibia.

Barnes, J.I. 2008. Community-based tourism and natural resource management in Namibia: Local and national economic impacts. In: Spenceley, A. (Ed). Responsible tourism: Critical issues for conservation and development. Earthscan, London, UK. 343-357.

Barnes, J.I. & Humavindu, M.N. 2003. Economic returns to land use options in Gondwana Cañon Park, Karas, Namibia. Unpublished Report, Nature Investments (Pty) Ltd. 73pp.

Barnes, J.I. & Jones, B. 2009. Game ranching in Namibia. In: Suich, H., Child, B. & Spenceley, A. (Eds.). *Evolution and innovation in wildlife conservation: from parks and game ranches to transfrontier conservation areas*. Earthscan London: pp113-126.

Barnes, J.I., MacGregor, J. & Weaver, L.C. 2002. Economic efficiency and incentives for change within Namibia's community wildlife use initiatives. *World Development* 30(4): 667-681.

Barnes, J.I., Nhuleipo, O., Muteyauli, P.I. & MacGregor, J. 2005. *Preliminary economic asset and flow accounts for forest resources in Namibia*. DEA Research Discussion Paper No 70, Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek, Namibia. 20pp.

Barnes, J.I., Schier, C. & van Rooy, G. 1997. *Tourist's willingness to pay for wildlife viewing and wildlife conservation in Namibia.* DEA Research Discussion Paper No. 15. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Namibia.

Barnes, J.I., Nhuleipo, O., Baker, A.C., Muteyauli, P.I. & Shigwedha, V. 2009a. *Wildlife resource accounts for Namibia, 2004*. DEA Research Discussion Paper No 79, Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek, Namibia. 26 pp.

Barnes, J., Saraiva, R., Mmopelwa, G., Mbaiwa, J., Magole, L. & Wamunyima, D. 2009b. *Okavango River Basin transboundary diagnostic analysis: Socio-economic assessment.* Unpublished Report, Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project, Luanda, Angola. 61pp.

Barnes, J., Alberts, M. & MacGregor, J. 2010. *The economic impact of climate change on land use in Namibia*. Unpublished Draft Paper, International Institute for Environment and Development (IIED) London, UK.

Berliner, D.D. & Desmet, P.G. 2008. A Systematic Conservation Assessment of the Richtersveld Municipal Area with Recommendations for Land Use Management. Richtersveld Company for Sustainable Development.

Birdsley, R.A. 1996. Carbon storage in United States forests. In: Sampson, R.N. & Hair, D. (Eds.) *Forest and global change, volume II: Opportunities for improving forest management.* American Forests, Washington, D.C., USA.

Booth, V., Martin, R. & Wilson, E. 2005. Capacity assessment for parks management in conservation at individual, institutional and systemic levels. Subcontract No. 2 of the Strengthening the System of National Protected Areas Project, Namibia. Namibia Nature foundation. 123 pp.

Branch, G. & Branch, M. 1981. *The Living Shores of Southern Africa*. Struik Publishers, Cape Town, South Africa.

Broennimann, O., Thuiller, W., Hughes, G., Midgley, G., Alkemade, J. & Guisan, A. 2006. Do geographic distribution, niche property and life form explain plants' vulnerability to global change? Global Change Biology 12(6): 1079-1093.

Brown, C.J. 2005. The historic distribution of some large mammals in Namibia. Internal report. Namibia Nature Foundation: 5pp.

Brown, C.J. 2009a. Overview of the "Namib-Skeleton Coast National Park" SAWMA News Bulletin 2009 – News Snippets. http://www.sawma.co.za/images/Namib_Skeleton.pdf accessed on 01/12/2009)

Brown, L.H. 2009b. *The effects of climate change on revenues to commercial agriculture and tourism enterprises in Namibia.* MSc Environmental Economics Thesis, University of York, York, UK. 83pp.

Brown, C.J., Canney, S., Martin, R. & Tarr, P. 2005. Conservation Needs Assessment. Subcontract No. 3 of the Strengthening the System of National Protected Areas Project, Namibia. Namibia Nature foundation. 123 pp.

Brown, B.E & Cochrane, K.L. 1991. Chlorophyll and distribution in the southern Benguela. Possible effects of global warming on phytoplankton and its implications for pelagic fish. *South African Journal of Science* **87**:233-242

Brown, C.J., Jarvis, A., Robertson, T. & Simmons, R. 1998. Bird diversity. In: Barnard, P. (Ed.). *Biological diversity in Namibia: a country study*. Windhoek: Namibian National Biodiversity Task Force. pp155-162.

Cihlar, J. 2007. Quantification of the regional carbon cycle of the biosphere: policy science and land use decisions. *Journal of Environmental Management* **85**: 785 – 790.

Clark, B.M., W.F. Meyer, C. Ewart-Smith, A. Pulfrich & Hughes, J. 1999. *Integrated overview of diamond mining in the Benguela Current region*. BCLME Thematic Report 3. For the Second regional workshop on the Benguela Current Large Marine Ecosystem. 12-16 April. 1999, Windhoek, Namibia.

Clements, R. 2009. *The economic cost of climate change in Africa*. Pan African Climate Justice Network. Practical Action Consulting Report.

Currie, H., Grobler, K. & Kemper, J. (Eds.). 2008. *Namibian Islands' Marine Protected Area*. WWF South Africa Report Series – 2008/Marine/003

De Klerk, N. 2004. Bush encroachment in Namibia. Ministry of Environment and Tourism.

Desmet, P. 2004. A Preliminary Estimate of Animal Carrying Capacity for the Namaqua National Park. Namaqua National Park, South African National Parks. Kamieskroon, South Africa.

Dewdney, R. 1996. Policy factors and desertification: analysis and proposals. Namibian Programme to Combat Desertification Steering Committee, Windhoek

de Wit, M. & Stankiewicz, J. 2006. Changes in surface water supply across Africa with predicted climate change. *Science* **311**:1917-1921.

Dietz, S., Hepburn, C. & Stern, N. 2008. Economics, ethics and climate change. Available at: http://ssrn.com/abstract=1090572.

Dirkx, E., Hager, C., Tadross, M., Bethune, S. & Curtis, B. 2008. *Vulnerability & Adaptation Assessment Namibia.* Desert Research Foundation of Namibia.

Driver, A., Cowling, R. & Maze, K. 2003. Planning for Living Landscapes: Perspectives and Lessons from South Africa. Washington, DC and Cape town, South Africa, Center for Applied Biodiversity Science (CABS) and Botanical Society of South Africa.

Driver, A., Maze, K., Lombard, A., Nel, J., Rouget, M., Turpie, J., Cowling, R., Desmet, P., Goodman, P., Harris, J., Jonas, Z., Reyers, B., Sink, K. & Strauss, T. 2004. South African National Spatial Biodiversity Assessment 2004: Summary Report. South African National Biodiversity Institute. Pretoria.

DVS. 1997. *Directorate of Veterinary Services Namibia.* Annual Report 1997*.* Epidemiology Section. Windhoek.

Engelbrecht, F. 2005. Simulations *of climate and climate change over southern and tropical Africa with the Conformal-Cubic Atmospheric Model.* In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 4: 57 - 74.

Engelbrecht, A., Golding, A., Hietkamp, S. & Scholes, B. 2004. *The potential for sequestration of carbon dioxide in South Africa. Manufacturing and Materials Technology*. Unpublished report, Council for Scientific and Industrial Research, Pretoria.

Everett, J. 1996. *Fisheries.* In: *Climate Change 1995. Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses*. Contribution of working Group II to the Second Assessment Report of the IPCC.WMO/UNEP.

Foti, J., DeSilva, L., McGray, H., Shaffer, L., Talbot, J., Werksman, J. 2009. *Voice and choice: opening the door to environmental democracy*. World Resources Institute, Washington DC.

Giess, W. 1971. A preliminary vegetation map of South West Africa. *Dinteria* **4**:5-114.

Government of Namibia. 2002. *Initial National Communication to the United Framework Convention on Climate Change*. July 2002. Available at

Griffin, E. 1998. Arachnid diversity. In: Barnard, P. (ed.). *Biological diversity in Namibia: a country study*. Windhoek: Namibian National Biodiversity Task Force. pp126-129.

Griffin, M. 1998. Reptile diversity. In: Barnard, P. (ed.). *Biological diversity in Namibia: a country study.* Windhoek: Namibian National Biodiversity Task Force. pp148-155.

GRN. 2002. *Initial National Communication to the United Framework Convention on Climate Change*. July 2002. Available at http://unfccc.int/resource/docs/natc/namnc1.pdf.

GRN. 2006. *Population Projections 2001-2031.* Windhoek, Central Bureau.

GRN, 2008. Understanding the Third National Development Plan 2007/2008 – 2011/2112. National Planning Commission.

Hailwa, J. 2009. Personal communication during information-gathering interview.

Hampton, I., Boyer, D.C.. Penney, A.J., Pereira, A.F. & Sardinha, M. 1999. *Integrated overview of fisheries of the Benguela Current region*. BCLME Thematic Report 1. For the Second Regional Workshop on the Benguela Current Large Marine Ecosystem. 12-16 April 1999, Windhoek, Namibia.

Hampton, I. 2003. Chapter 5: Harvesting the Sea. In: Molloy, F. & Reinikainen (Eds.).*Namibia's Marine Environment*. Directorate of Environmental Affairs of the Ministry of the Environment and Tourism, Namibia. ISBN 0-86976-596-5.

Harring, S. & Odendaal, W. 2006. No resettlement available – An assessment of the expropriation principle and its impact on land reform in Namibia. Legal Assistance Centre, Windhoek.

Harring, S. & Odendaal, W. 2007. Legal Assistance Centre, Windhoek.

Hayden, T. & Begley, S. 1997. *Cold Comfort.* Newsweek Magazine. August 11th.

Hewitson, B., Engelbrecht, F., Tadross, M. & Jack, C. 2005b. General Conclusions on Development of Plausible Climate Change Scenarios for Southern Africa. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 5, pp75-79.

Hewitson, B., Tadross, M. & Jack, C. 2005. Climate Change Scenarios: Conceptual Foundations, Large Scale Forcing, Uncertainty and the Climate Context. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 2, pp21-38.

Hewitson, B., Tadross, M. & Jack, C. 2005a. Scenarios developed with empirical and regional climate model-based downscaling. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 3, pp39-56.

Hewitson, B.C., Tadross, M. & Jack, C. 2005c. Historical Precipitation Trends over Southern Africa: A Climatology Perspective. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 18, pp319-324.

Heyns, P.S., Montgomery, J. & Pallett (Eds.). 1998. *Namibia's Water. A Decision Makers' Guide.* Desert Research Foundation of Namibia, Windhoek.

Hijmans, R.J., Cameron, S.E., Parra, J.L., Jones, P.G. & Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* **25**:1965-1978.

Hughes, P., Brundrit, G.B. and Searson, S. 1992. The vulnerability of Walvis Bay to rising sea levels. *Journal of Coastal Research* **8**:868-881.

Hulme, M. (Ed.). 1996. *Climate change and southern Africa: an exploration of some potential impacts and implications for the SADC region*. Report commissioned by WWF international and co-ordinated by the Climate Research Unit, UEA, Norwich, UK

Hulme, M., Arntzen, J., Downing, T.E., Leemans, R., Malcolm, J., Reynard, N., Ringrose, S. & Rogers, D. 1996. *Climate change and southern Africa: an exploration of some potential impacts and implications in the SADC Region.* CRU/WWF, Norwich, UK, 104pp.

Humavindu, M.N. 2002. Economics without markets: policy inferences from nature-based tourism studies in Namibia. Department of Environmental Affairs, Ministry of Environment and Tourism. Discussion Paper No.49.

Hutchinson, P. 1995. The climatology of Namibia and its relevance to the drought situation. In: *Coping witharidity drought impacts and preparedness in Namibia*. NEPRU. WHK. pp17-37.

Hutchinson, P. 1998. *Notes on the Namibia volumetric annual rainfall.* Namibia Meteorological Services, unpublished report.

Hutchinson, M.F. 2001. ANUSPLIN Version 4.2 User Guide. Canberra, Centre for Resource and Environmental Studies, The Australian National University.

IPCC. 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Working Group II Contribution to the Third Assessment Report of the IPCC. Geneva, Switzerland.

IPCC. 2001a. *Climate Variability 2001. Impacts, Adaptation, and Vulnerability*. McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. & White, K.S. (Eds.) Cambridge Press, Cambridge, UK.

IPCC. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Summary for Policymakers*. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report.

IPCC. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Summary for Policymakers. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report.

IPPR Institute for Public Policy Research. 2009. *National accounts 1990-2006 data base.* Available at: www.ippr.org.na.

Jacobson, P.J., Jacobson, K.M. & Seely, M.K. 1995. *Ephemeral rivers and their catchments: sustaining people and development in western Namibia*. Desert Research Foundation of Namibia, Windhoek. 160pp.

Jarvis, A. & Robertson, T. 1997. *Endemic birds of Namibia: evaluating their status and mapping their hotspots*. DEA Research Discussion Paper. 14:102 pp.

Jones, B.T.B. & Barnes J.I. 2009. Preparing for REDD in dryland forests: investigating the options and potential synergy for REDD payments in the miombo eco-region (Namibia country study). International Institute for Environment and Development (IIED), London, UK. 50pp.

Kiker, G.A. 1999. *South African country study on climate change synthesis report for the vulnerability and adaptation assessment section* (DRAFT). School of Bioresources Engineering and Environmental Hydrology.

Koch, H. 2009. Pers. comm. and as quoted in New Era, 20 March 2009.

Lancaster, N.I. 1989. *The Namib Sand Sea: dune forms, processes and sediments*. AA Balkema, Rotterdam.

Lange, G-M. 2003. *National Wealth, Natural Capital and Sustainable Development in*

Langhammer, P.F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall, W., De Silva, N., Edgar, G.J., Eken, G., Fishpool, L.D.C., da Fonseca, G.A.B., Foster, M.N., Knox, D.H., Matiku, P., Radford, E.A., Rodrigues, A.S.L., Salaman, P., Sechrest, W. & Tordoff, A. W. 2007. Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems. Gland, Switzerland, IUCN.

Leary, N., Adejuwon, J., Barros, V., Batimaa, P., Biagini, B., Burton, I., Chinvanno, S., Cruz, R., Dabi, D., de Comarmond, A., Dougherty, B., Dube, P., Githeko, A., Abou Hadid, A., Hellmuth, M., Kangalawe, R., Kulkarni, J., Kumar, M., Lasco, R., Mataki, M., Medany, M., Mohsen, M., Nagy, G., Njie, M., Nkomo, J., Nyong, A., Osman, B., Sanjak, E., Seiler, R., Taylor, M., Travasso, M., von Maltitz, G., Wandiga, S & Wehbe, M. 2007. *A stitch in time: lessons for climate change adaptation from the AIACC project.* Working Paper No. 48.

Lombard, A.T. 1998. *Literature Review: the effects of climate change on marine biodiversity in South Africa.* Unpublished report submitted to the FRD.

Loots, S. 2005. *Red Data Book of Namibian Plants*. Pretoria & Windhoek: Southern African Botanical Diversity Network Report No. 38. SABONET:124 pp.

Maartens, L. 2003. Biodiversity. In: Molloy, F. & Reinikainen (Eds.). *Namibia's Marine Environment.* Directorate of Environmental Affairs of the Ministry of the Environment and Tourism, Namibia. ISBN 0-86976-596-5.

Mannheimer, C. 2008. *Flowers and succulents of the southern Namib.*

Martin, R.B. 2002. *Southern Savanna Buffalo*. Unpublished report. Windhoek: Ministry of Environment & Tourism and Namibia Nature Foundation: 106pp.

Martin, R.B. 2003. *Roan, Sable and Tsessebe*. Unpublished report. Windhoek: Ministry of Environment & Tourism and Namibia Nature Foundation: 96pp.

Martin, R.B. 2005. *Elephants*. Unpublished report. Windhoek: Ministry of Environment & Tourism and Namibia Nature Foundation: 104pp.

May, R.B. 2010. Ecological sciences and tomorrow's world. *Phil. Trans. T. Soc. B.* **365**:41-47.

MAWRD. 1995. National Agriculture Policy. Ministry of Agriculture, Water and Rural Development.

Mbaiwa, J.E. The success and sustainability of community-based natural resource management in the Okavango Delta, Botswana. *South Africa Geographic Journal* **86**:44-53.

McMichael, A.J., Campbell-Lendrum, D.H., Corvalan, C.F., Ebi, K.L., Githeko, A., Scheraga, J.D. & Woodward, A. (Eds.). 2003. Climate change and human health: risks and responses. World Health Organisation, Geneva.

Mendelsohn, J. 2006. Farming systems in Namibia. RAISON, for the Namibia National Farmers Union. Windhoek.

Mendelsohn, J. & el Obeid, S. 2005. *Forests and woodlands of Namibia*. RAISON, Windhoek.

Mendelsohn, J., Jarvis, A., Roberts, C. & Robertson, T. 2002. *Atlas of Namibia*. Cape Town: Ministry of Environment & Tourism. David Philip.

Mendelsohn, J., el Obeid, S., de Klerk, N. & Vigne, P. 2006. *Farming systems in Namibia*. Namibia National Farmers Union (NNFU), Windhoek, Namibia. 80pp.

MET Ministry of Environment and Tourism. 1997. *Commission of Enquiry into Gambling in Namibia*. GRN, Unpublished Report.

MET Ministry of Environment and Tourism Namib-Naukluft National Park Brochure Source: www.met.gov.na Accessed: 03/12/2009

MET Ministry of Environment and Tourism Skeleton Coast National Park Brochure Source: www.met.gov.na Accessed: 03/12/2009

MET Ministry of Environment and Tourism Sperrgebiet National Park Brochure Source: www.met.gov.na Accessed: 03/12/2009

Midgley, G., Hughes, G., Thuiller, W., Drew, G. & Foden, W. 2005. Assessment of potential climate change impacts on Namibia's floristic diversity, ecosystem structure and function. Report for: Namibian National Biodiversity Programme, Directorate of Environmental Affairs by the Climate Change Research Group, South African National Biodiversity Institute (SANBI), Kirstenbosch Botanical Garden. Cape Town.

MLR. 2005. Recommendations, strategic options and action plan on land reform in Namibia. Permanent Technical Team (PTT) on Land Reform, Ministry of Lands and Resettlement.

Molloy, F. 2003a. Chapter 3: Biological Environment. In: Molloy, F. & Reinikainen (Eds.) *Namibia's Marine Environment*. Directorate of Environmental Affairs of the Ministry of the Environment and Tourism, Namibia. ISBN 0-86976-596-5.

Molloy, F. 2003b. Chapter 4: Coastal Environment. In: Molloy, F. & Reinikainen (Eds.) *Namibia's Marine Environment*. Directorate of Environmental Affairs of the Ministry of the Environment and Tourism, Namibia. ISBN 0-86976-596-5.

Morant, P.D. 1999. *Benguela Current large marine ecosystem: synthesis of information on the coastal environment between the Congo River mouth and Cape Agulhas*. UNDP. CSIR REPORT ENV-S-C 98101.

NACOMA. 2009. *Marine Protected Areas*. Source: www.nacoma.org.na Accessed: 30/11/2009.

NACSO 2004. *Namibia's communal conservancies: a review of progress and challenges*. Namibian Association of CBNRM Support Organisations, Windhoek, Namibia. 80pp.

NACSO 2006. *Namibia's communal conservancies: a review of progress and challenges in 2005*. Namibian Association of CBNRM Support Organisations, Windhoek, Namibia. 104pp.

NACSO 2008. *Namibia's communal conservancies: a review of progress and challenges in 2007*. Namibian Association of CBNRM Support Organisations (NACSO), Windhoek, Namibia. 120pp.

NAU 2003. "A Framework for Sustainable Land Use and Land Reform in Namibia". Windhoek: Namibia Agricultural Union.

New Era. 2009. Background of the Land Reform Program in Namibia. Media release issued by Minister of Lands and Resettlement, 3 September 2009, New Era newspaper.

Newsham, A. & Thomas, D. 2009. *Agricultural adaptation, local knowledge and livelihoods diversification in North-0Central Namibia*. Tyndall working Paper 140.

NMS. 1998. *Feature Page. The El Niño/Southern Oscillation (ENSO).* The WHOT? Bulletin. August1998. Namibia Meteorological Services, Windhoek.

NPC, 2004. Namibia 2004 Millenium Development Goals Report. National Planning Commission and United Nations report.

NPC. 2007. Poverty Profile of Kunene Region. National Planning Commission.

NTB Namibia Tourism Board. 2008. *Namibia Tourism Satellite Account - second edition.* Namibia Tourism Board, Windhoek, Namibia. 20pp.

Odendaal, P.B., Owen, D.L., Bosman, A.P.G., Von Gadow, S.K. & Van der Zel, D.W. 1983. *South African forestry handbook.* Gutenberg Book Printers, Pretoria, South Africa.

Oertzen, D.O. 2008. Namibian national issues report on the key sector of energy with a focus on mitigation. UNDP Environment and Energy Group Report.

Orasecom. 2008. *Orange-Senqu River Basin.* Preliminary transboundary diagnostic analysis. UNDP and GE. 197pp.

Parry, M., Arnell, N., Berry, P., Dodman, D., Fankhauser, S., Hope, C., Kovats, S., Nicholls, R., Satterthwaite, D., Tiffin, R., Wheeler, T. 2009. *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates*, International Institute for Environment andDevelopment and Grantham Institute for Climate Change, London.

Possingham, H. P., Ball, I. R. & Andelman, S. 2000. Mathematical methods for identifying representative reserve networks. Quantitative methods for conservation biology. S. Ferson and M. Burgman. New York, Springer-Verlag: 291-305.

Price Waterhouse Cooper. 2005. Cost-benefit analysis of the horticultural sector. Working document.

Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat, 1971.

Reid, H., Sahlén, L., Stage, J. & MacGregor, J. 2007. The economic impact of climate change in Namibia: how climate change will affect the contribution on Namibia's natural resources to its economy. Environmental Economics Programme Discussion Paper 07-02. London: International Institute for Environment and Development.

Roux, J-P. 2003. Risks. In: Molloy, F. & Reinikainen, T. (Eds.) *Namibia's Marine Environment*. Directorate of Environmental Affairs, Ministry of Environment and Tourism. 162pp.

Rowlands, I. 1996. Going with the floe: South Africa and global climate change. Social Policy Series, *Policy: Issues and Actors* 9(2), Centre for Policy Studies, London School of Economics and Political Science: London.

Sakko, A. 1998. Biodiversity of Marine Habitats. In: Bernard, P (Ed.). *Biological Diversity in Namibia – a country study.* Windhoek: Namibian National Biodiversity Task Force. Pp. 189-221.

Scheiter, S. & Higgins, S. I. 2009. Impacts of climate change on the vegetation of Africa: an adaptive dynamic vegetation modelling approach. *Global Change Biology* **15:**2224-2246.

Scholes, B. & van der Merwe, M. 1995. South African green house inventory. *CSIR Report FOR-DEA 918*, CSIR: Pretoria.

Schulze, R.E., Kiker, G.A. & Kunz, R.P. 1993. *Global climate change and agricultural productivity in southern Africa.* Global Environmental Change: December 2009.

Schulze, R.E. (ed.). 2005. *Climate change and water resources in southern Africa*. Studies on scenarios, impacts, vulnerabilities and adaptation. WRC Report No: 1430/1/05. 470 pp.

Schulze, R.E. 2005. Case Study 1: Changes in hydroclimatic baselines under different hypothetical, but plausible, scenarios of climate change: initial findings on sensitive and robust hydroclimatic zones in southern Africa. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 12, pp233-240.

Schulze, R.E. 2005a. Case Study 2: Potential impacts of shifts in hydroclimatic zone on design hydrology from small catchments in southern Africa. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 13, pp24 -247.

Schulze, R.E. 2005b. Selection of a suitable agrohydrological model for climate change impact studies over southern Africa. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 7, pp95-110.

Schulze, R.E. 2005c. Setting the scene: the current hydroclimatic "landscape" in southern Africa. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 6, pp83-94.

Schulze, R.E., & Dlamini, D.J.M. 2005. Case Study 3: Potential impacts of a hypothetical, but plausible, climate change scenario on within-country reservoir management for irrigation, and out-of-country flow obligations in the Mbuluzi Catchment, Swaziland. *In*: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 14, pp249-254.

Schulze, R.E., Hewitson, B.C., Vogel, C. & Engelbtecht, F. 2005a. Synthesis and recommendations for future research. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation.* Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 28, pp453-455.

Schulze, R.E., Horan, M.J.C. & Gray, R. 2005. Sensitivity studies of hydrological responses in the Thukela Catchment to spatial and temporal representations when using a baseline and a projected future climate scenario. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 11, pp211-232.

Schulze, R.E., Lumsden, T.G., Horan, M.J.C., Warburton, M. & Maharaj, M. 2005b. An assessment of impacts of climate change on agrohydrological responses over southern Africa. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 9, pp141-189.

Seely, M.K. 2004. *The Namib: Natural history of an ancient desert*. Desert Research Foundation of Namibia, Windhoek.

Seely, M.K. & Griffin, M. 1986. Animals of the Namib Desert: interactions with their physical environment. *Revue de Zoologie Africaine* 100: 47-61.

Shannon, L.V. & O'Toole, M.J. 1998. *Integrated overview of the oceanography and environmental variability of the Benguela Current region.* BCLME Thematic Report 2. For the Second Regional Workshop on the Benguela Current Large Marine Ecosystem. 12-16 April 1999, Windhoek, Namibia.

Sherbourne, R. 2009. *Guide to the Namibian economy 2009.* Institute for Public Policy Research (IPPR), Windhoek, Namibia. 379pp.

Shivute, N. 2009. Personal communications during information-gathering interview.

SIAPAC. 2007. *Study on characteristics of demand of tourists and use patterns of protected areas in Namibia.* Ministry of Environment and Tourism, Windhoek, Namibia. 154pp.

Simmons, R.E. & Brown C.J. In prep. Birds to watch in Namibia: red, rare and endemic species.

Smith, R.J. 2004. Conservation Land-Use Zoning (CLUZ) software. From http://www.mosaic-conservation.org/cluz.

Smithers, R.H.N. 1983. The mammals of the southern African subregion. Pretoria: University of Pretoria: 736pp.

Southern Waters Ecological Research & Consulting & Energy & Development Research Centre. University of Cape Town. Sponsored by USAID and administered by the Joint Center for Political and Economic Studies Inc. under a subcontract agreement from Nathan Associates Inc. RSA. 64 pp.

Tarr, J. 1997. *Desktop survey on waste management in Namibia 1996-1997*. Conducted for the Namibia Nature Foundation and NORAD.

Tarr, J. 1999. *Namibia's initial country study on climate change.* Report number 2: An Overview of Namibia's Vulnerability to Climate Change. Desert Research Foundation of Namibia. 161pp.

Thomas, D.S.G., Knight, M. & Wiggs, G.F.S. 2005. Remobilisation of southern African desert dune systems by twenty-first century global warming. *Nature* **435**: 1218-1221.

Thornton, P.K., Jones, P.G., Owiyo, T., Kruska, R.L., Herrero, M., Kristjanson, P., Notenbaert, A., Bekele, N. & Omolo, A., with contributions from Orindi, V., Otiende, B., Ochieng, A., Bhadwal, S., Anantram, K., Nair, S., Kumar, V. & Kulkar, U. 2006. *Mapping climate vulnerability and poverty in Africa*. Report to the Department for International Development, ILRI, PO Box 30709, Nairobi 00100, Kenya. Pp 171.

Thuiller, W., Midgley, G. F., Hughes, G. O., Bomhard, B., Drew, G., Rutherford, M. C. & Woodward, F. I. 2006. Endemic species and ecosystem sensitivity to climate change in Namibia*. Global Change Biology* **12**: 1–18.

Travel News Namibia. 2009. TASA Commemorative 2009.

Turpie, J. & Joubert, A. 2001. Estimating the potential impacts of a change in river quality on the tourism value of Kruger National Park: An application of travel cost, contingent and conjoint valuation methods. *Water SA* **27**(3): 387-398.

Turpie, J., Lange, G-M., Martin, R., Davies, R. & Barnes J. 2004. Economic value and financing of Namibia's protected areas. Ministry of Environment and Tourism, Windhoek, Namibia.

Turpie, J. K., Winkler, H. & Midgley, G. 2004. Economic impacts of climate change in South Africa: a preliminary analysis of unmitigated damage costs. In: Blignaut, J.N. & de Wit, M.P. *Sustainable Options*. UCT Press, pp130-160.

Turpie, J., Barnes, J., Lange, G.-M. & Martin, R. 2010. The economic value of Namibia's protected area system and case for increased investment. Report to SPAN and DEA.

UNEP. 1996. *Handbook on methods for climate change impact assessment and adaptation strategies.* Draft Version 1.3. Adaptation/impacts.

Usman, M.T & Reason, C.J.C. 2004. Dry spell frequencies and their variability over southern Africa*. Climate Research* **26**:199–211.

Verlinden, A. & Dayot, B. 2000. Working with local knowledge systems in a GIS for natural resource assessment, planning and management in North-Central Namibia. In *Proceedings of the Regional Workshop on Spatial Approaches for Land Use and Local Governance*. pp.63-78.

von Maltitz, G., Scholes, B & Midgley, G. 2005. *Impacts and adaptations to climate change by the biodiversity sector in southern Africa*. SIR, Environmental and South African Natural Biodiversity Institute (SANBI).

Warburton, M. & Schulze, R.E. 2005. Detection of climate change: a review of literature on changes in temperature, precipitation and streamflow, on detection methods and data problems. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 15, pp257-274.

Warburton, M. & Schulze, R.E. 2005a. Detection of trends over time in hydrological drivers and responses over southern Africa. In: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 17, pp297-318.

WHO/CTD. 1998. World Health Organisation. Division of control of tropical diseases. Available at: http://www.who.ch/ctd.

WRI. 1998. *1998-99 World Resources. A guide to the global environment. environmental change and human health.* World Resources Institute, UNEP, UNDP. The World Bank.

WRI. 2006. http://earthtrends.wri.org/text/population-health/country-profile-129.html

WTTC. 2006. *Namibia: the impact of travel and tourism on jobs and the economy.* Namibia Tourism Board and Ministry of Environment and Tourism, Windhoek, Namibia. 60pp.

Yeaton, R.I. 1988. Structure and function of the Namib dune grasslands: characteristics of the environmental gradients and species distributions. *Journal of Ecology* **76**: 744-758