Development of an Inventory of Ecosystem Services in Namibia

Final Report

Namibia Nature Foundation

In collaboration with:

SAIEA, Sustainable Solutions Trust, Research and Information Services of Namibia and eftec

2016

Acknowledgements

The authors would in particular like to thank Dr. Konrad Uebelhoer and Dr. Martin Nowack of GIZ, Ms. Ece Ozdemiroglu of eftec, Gillian Maggs-Kölling, Theo Wassenaar, John Irish (Gobabeb Training and Research Centre) and Mutjinde Katjiua (Namibia University of Science and Technology NUST) who reviewed and provided detailed comments to support the finalisation of the report. Ben Nathanael designed and compiled the maps of each ecosystem zone. This study was financed by the Resource Mobilisation Project of the Ministry of Environment and Tourism and the Deutsche Gesellschaft für international Zusammenarbeit (GIZ) GmbH. The Resource Mobilisation Project is part of the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). The BMUB supports this initiative on the basis of a decision adopted by the German Bundestag.

Contributing Authors

Lawrie Harper-Simmonds, Dr John Mendelsohn, Dr Jean-Paul Roux, John Pallet, Dr Chris Brown, Angus Middleton and Johannes Kruse

Edited: Catherine Birch

Updates

This inventory of ecosystem services is a first step, and should lead to debate, research, and further iteration. As more knowledge and data are gathered and our understanding of ecosystem services is improved, this inventory can potentially be updated. To this purpose, contributions can be submitted to the email address below. Please note that only well-developed submissions backed up by data/evidence/qualified opinion will be considered.

Enquiries

Namibia Nature Foundation
76 – 78 Frans Indongo Street
Windhoek, Namibia
Tel: + 264 61 248345
Fax: +264 61 248344
Email: info@nnf.org.na

Acronyms

CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
FEGS-CS	Final Ecosystem Goods and Services Classification System
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit
MA	Millennium Ecosystem Assessment
MET	Ministry of Environment and Tourism
MFMR	Ministry of Fisheries and Marine Resources
NBSAP2	Namibia's Second National Biodiversity Strategy and Action Plan
NDC	Namibia Development Corporation
NE Rivers	North-East Rivers
NHIES	National Household Income and Expenditure Survey
ResMob	Resource Mobilisation for the Conservation of Biodiversity
SANUMARC	Sam Nujoma Marine and Coastal Resources Research Centre
SEEA-EEA	System of Environmental-Economic Accounts: Experimental Ecosystem Accounting
SNA	System of National Accounts
TEEB	The Economics of Ecosystems and Biodiversity
UKNEA	United Kingdom National Ecosystem Assessment
UNAM	University of Namibia
USEPA	United States Environmental Protection Agency

Table of Contents

Executive Summary

The Millennium Ecosystem Assessment (MA) found that over the course of the 20th Century, humans have extensively and rapidly changed ecosystems in a way that has diminished their capacity to deliver services; indeed, it was estimated that 60 percent of ecosystem services are being degraded or used unsustainably. Ecosystem services contribute to benefits that are ultimately used and enjoyed by people, and consequently affect human well-being. The ecosystem services framework is therefore useful in identifying environmental issues which need to be addressed, as well as demonstrating their importance to policy and decision makers.

This report seeks to identify ecosystem services in Namibia, assess trends in the delivery of these ecosystem services and the drivers of change affecting their delivery, and prioritise ecosystem services for mainstreaming into decision-making. To ensure that this is consistent with the outcomes of currently ongoing and potential future initiatives of the Resource Mobilisation for the Conservation of Biodiversity (ResMob) project, the report draws on many of the concepts and definitions provided by the UN System of Environmental-Economic Accounts: Experimental Ecosystem Accounting (SEEA-EEA) and adopts the UK National Ecosystem Assessment (UK NEA) as a key guiding reference. The study represents an example of a scoping study for undertaking a TEEB Country Study, and consequently can provide the basis for the main study phase of a TEEB Country Study.

A total of 17 ecosystem zones (13 terrestrial, 4 coastal/marine) were identified in Namibia. The terrestrial ecosystem zones were adapted from existing classifications of vegetation zones in Namibia and further distinguished based on distinct collections of characteristics. The coastal/marine ecosystem zones were delineated mainly on the basis of oceanographic and bathometric criteria which also form important functional distinctions in maritime and fisheries management.

These ecosystem zones were then used as the basis from which to present an inventory of ecosystem services at the sub-National level, using the Common International Classification of Ecosystem Services (CICES). Six broad drivers of change were adopted when assessing trends in the flow of identified ecosystem services: habitat change, exploitation, pollution, climate change, illegal use and invasive species.

The principal driver of change in Namibia over the past 50 years has been exploitation, which is the result of increased demand for goods and services due to growing human populations and the opening up of the country post-independence. At the national level, the flows of all provisioning services in terrestrial ecosystem zones are estimated to have increased as a result of increased exploitation; those increasing most significantly have been services related to livestock (in particular cattle farming and keeping), plants for materials and energy use (particularly firewood) and surface water (for both drinking and non-drinking uses). Exploitation is expected to remain an upward pressure on the flows of almost all terrestrial provisioning services.

However many ecosystem services are facing increased pressures on their flows. While livestock farming and keeping has increased, particularly in communal areas, this has led to overgrazing and consequently land degradation in many areas; this is represented by declines in associated regulation and maintenance services, such as those related to soil formation and composition (9 of

13 terrestrial ecosystem zone assessments indicated that soil formation and composition services had been negatively affected). As a result of this, the carrying capacity of these areas has been decreased, and consequently their future ability to deliver the services related to livestock farming and keeping may be decreased.

The above example illustrates the interlinked nature of many ecosystem services: the exploitation of some may impact on the delivery of others (or on its own future delivery if it operates in a negative feedback loop). Furthermore, these linkages extend beyond the borders of a given ecosystem, and can affect the delivery of ecosystem services in neighbouring ecosystem, which in some cases may be in different countries.

Across many ecosystem zones, the same pressures are evident. Land degradation caused by overgrazing as described above is one, with bush encroachment another; the latter is thought to be reducing groundwater recharge rates. In riverine ecosystem zones, reduced flows, as a result of the abstraction of water, and pollution, from industrial discharge or agricultural return flows, are common. The assessments of marine ecosystem zones illustrate that the overexploitation of the small pelagic fish stocks along the Continental Shelf has had significant negative impacts on neighbouring ecosystem zones and their services, including the provision of food from hake in the Shelf-Break and Slope zone, and the provision of guano for fertiliser in the Coastal and Near-Shore zone.

It is also clear that there is a significant amount of uncertainty about the flows of certain ecosystem services and how various pressures will affect them going forwards. This is much more the case for regulation and maintenance and cultural services than it is for provisioning; it is much easier to understand the effects of drivers of change on services of which uses and therefore flows can be directly observed. There is clearly a need for greater research into many regulation and maintenance and cultural services to better understand them.

In order to provide the basis for incorporating ecosystem services into decision-making, the report suggests five criteria for prioritising ecosystem services for this purpose. These criteria (and examples of services prioritised by these criteria) are: current and expected future impacts on the flow of the service (livestock farming and the provision of groundwater); services affected by critical threats identified in Namibia Second National Biodiversity Strategy and Action Plan (unsustainable water uses: maintenance of the condition of freshwaters); economic importance (recreational tourism); affected population (services in the North-East Rivers and Northern Kalahari Woodlands ecosystem zones given the incidence of poverty among these populations) and availability of data (traded provisioning services such as crops and livestock).

One way of incorporating ecosystem services into policy and decision making is to undertake economic valuations of these services. Where possible, this can attribute monetary values to services, alongside emphasising their linkages with other ecosystem services and especially those for which it is often not possible or appropriate to attribute a monetary value. This is discussed in greater detail in the accompanying report, *Roadmap for the economic valuation of ecosystem services in Namibia* (page 244).

1 Introduction

1.1 Background

The preservation of biodiversity has gained significant international attention in recent years, particularly since the publication of Millennium Ecosystem Assessments in 2005 and the initial TEEB (The Economics of Ecosystems and Biodiversity) Report[1] and those that have followed. These have given rise to a clear call for an increased focus on ecosystems and their services arising from the Convention on Biological Diversity (CBD)[2] and in particular through the Aichi Targets[3]. The TEEB report helped to highlight the wider costs of biodiversity degradation that were not necessarily being taken into consideration in economic decision making. The Aichi targets in turn identify the importance of the values of ecosystems and their services, and in particular the need to mobilise resources to conserve biodiversity (Target 20).

The Constitution of Namibia (Article 95) recognizes the importance that ecosystems and biodiversity play in contributing to human welfare. However, preventing degradation of biodiversity is only possible with the support of both the public and private sectors. Demonstrating the economic value of ecosystems and their services is key to driving support among institutions, and therefore also in generating appropriate investment to ensure that policies to prevent the degradation of ecosystems and the quality and/or quantity of their services can be properly implemented. This is one of the goals of the resource mobilization (ResMob)[4] project being co-ordinated by the Ministry of Environment and Tourism (MET) with the support of the GIZ.

1.2 Objectives

The development of an inventory of Ecosystem Services in Namibia is an important component of the ResMob project. This inventory helps to map out ecosystem zones and their services in a manner that can assist with mainstreaming ecosystem services into policy making for public, corporate and private decisions. There are therefore 4 key objectives of the report:

- Identify ecosystem services in Namibia at a sub-national level;
- Assess the trends in the delivery of these ecosystem services and the underlying drivers of change;
- Provide suggested criteria for prioritising ecosystem services for mainstreaming into decision-making[5]; and

[1] TEEB, 2010
[2] https://www.cbd.int/doc/legal/cbd-en.pdf
[3] The full text of the CBD Decision on the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets is found in UNEP/CBD/COP/DEC/X/2 and available here: https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-02-en.pdf.
[4] The overall objective of the ResMob project is to mobilise additional funding for biodiversity conservation, such that Namibia's Second National Biodiversity Strategy and Action Plan (NBSAP2) can be adequately financed. Additional information about the project can be found here: https://www.giz.de/en/worldwide/32010.html.
[5] The initial terms of reference required the consultancy to prioritise ecosystem services for economic valuation studies. Following discussion with the MET-GIZ team, this objective was reworked so that the criteria for prioritisation, along with the services relevant to these criteria, are suggested in the report for the purpose of mainstreaming (to better reflect that mainstreaming is the ultimate goal and economic valuation is just one way to achieve this).

- Ensure consistency with the outcomes of currently ongoing and potential future initiatives in the ResMob project, namely environmental-economic accounting, experimental ecosystem accounting and conducting a TEEB Country Study.

An additional objective of the consultancy is to develop an indicative roadmap that suggests how the economic valuation of ecosystem services could be undertaken in Namibia. This is presented in the accompanying *Roadmap for the Economic Valuation of Ecosystem Services in Namibia* document (page 244), in addition to an overview of economic valuation concepts. Economic valuation can be an effective (but is not the only) tool to assist with mainstreaming ecosystem services into decision-making.

1.3 Structure

The report proceeds as follows:

- Section 2 provides an overview of the ecosystem services approach;
- Section 3 presents the methodology that was followed for developing the inventory of ecosystem services;
- Section 4 describes some key ecological processes in Namibia;
- Section 5 discusses the inventory of ecosystem services in each ecosystem zone;
- Section 6 presents a summary of the findings at the national level;
- Section 7 provides a roadmap for the prioritisation of ecosystem services; and
- Section 8 concludes.

The accompanying *Roadmap for the Economic Valuation of Ecosystem Services in Namibia* is presented at the end of this document.

2 The ecosystem services approach

2.1 Ecosystem services

In the face of increasing pressures on the natural environment, the ecosystem services approach has received significant attention in recent years. The concept was popularized by the Millennium Ecosystem Assessment (MA)[6], which defined ecosystem services as "*benefits people obtain from ecosystems*". Among its key findings was that over the last century, humans have extensively and rapidly changed ecosystems in a way that has diminished their capacity to deliver services; as a result of this, it was estimated that 60 percent of ecosystem services are being degraded or used unsustainably.

The ecosystem services approach serves to explore the dependency of human well-being on ecosystems and their services. It provides a clear link between biophysical science, social science and policy, ultimately allowing for well-informed, evidence-based and integrated decision- and policy-making. Potschin and Haines-Young (2011) argue that the anthropocentric and utilitarian perspective embraced by the ecosystem services approach offers a way to conceptualise win-win situations and trade-offs between environmental protection and human well-being, and strengthens the case for conservation by complementing ethical considerations with economic arguments. The framework linking ecosystems, ecosystem services and human well-being is discussed in Section 2.2.

The MA defined four categories of ecosystem services: provisioning (products obtained from ecosystems e.g. food); regulating (benefits obtained from the regulation of ecosystem processes e.g. carbon sequestration); supporting (services that are necessary for the production of all other ecosystem services e.g. nutrient recycling) and cultural (nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences e.g. recreation).

Subsequent to the publication of the MA a discussion arose surrounding the appropriate boundary for the categorisation of ecosystem services. The inclusion of supporting services, which effectively represent inputs to the production of other services, could result in the double-counting of the contribution of ecosystem services to the production of benefits. The Economics of Ecosystems and Biodiversity (TEEB) report attempted to address this by removing supporting services in favour of habitat services (provision of habitat for migratory species and gene-pool "protectors")[7]. This reflected a shift in the focus towards final ecosystem services, where 'final' reflects the point of interaction between humans and ecosystems.

Most recently, the Common International Classification of Ecosystem Services (CICES)[8] and the U.S. Environmental Protection Agency's (USEPA) Final Ecosystem Goods and Services Classification System (FEGS-CS)[9] have been developed with the intention of harmonising the classification of ecosystem goods and services. An additional objective of the former was to provide consistency with

[6] MA, 2005
[7] de Groot et al, 2010
[8] Haines-Young and Potschin, 2013
[9] Landers and Nahlik, 2013

environmental-economic accounting methods[10], and consequently a version of CICES is adopted by the UN System of Environmental-Economic Accounts: Experimental Ecosystem Accounting (SEEA-EEA)[11] framework, which defines ecosystem services as "*the contributions of ecosystems to benefits used in economic and other human activity*"[12].

As with TEEB, both CICES and FEGS-CS make an explicit attempt to avoid double counting through only including final ecosystem services. However the two take quite distinct approaches in classifying ecosystem services. CICES broadly follows the approach established by the MA and TEEB, but defines only three categories under which ecosystem services are classified: provisioning; regulation and maintenance; and cultural. These three broad CICES categories are defined in a similar way to the corresponding categories in the MA.

The FEGS-CS on the other hand adopts an entirely different approach. It defines twenty-one categories of FEGS (e.g. water, flora, presence of the environment), with FEGS only identified when a category of FEGS is connected to a specific beneficiary and an environment. There are ten categories (e.g. agricultural, recreational) and 38 total sub-categories (e.g. agricultural – irrigators, recreational – hunters) of beneficiaries, and 3 classes (aquatic, terrestrial, atmospheric) and 15 total sub-classes (e.g. aquatic – rivers and streams, terrestrial – forests) of environments. The FEGS-CS report presents a matrix that identifies the relevant FEGS categories to each of the beneficiary sub categories and environmental sub-classes.

This report adopts the CICES classification for ecosystem services. A major benefit of following CICES is that it will be broadly consistent with the classification of ecosystem services used in the SEEA-EEA. Furthermore, the classification in CICES arguably allows for a simpler (if less comprehensive) elaboration of an inventory of ecosystem services in Namibia than that in the FEGS-CS: CICES specifies 48 'classes' of ecosystem services, compared to 338 unique sets of FEGS in FEGS-CS. The CICES classification is discussed in further detail in Section 3.3.

2.2 Ecosystems, ecosystem services and well-being: a conceptual framework

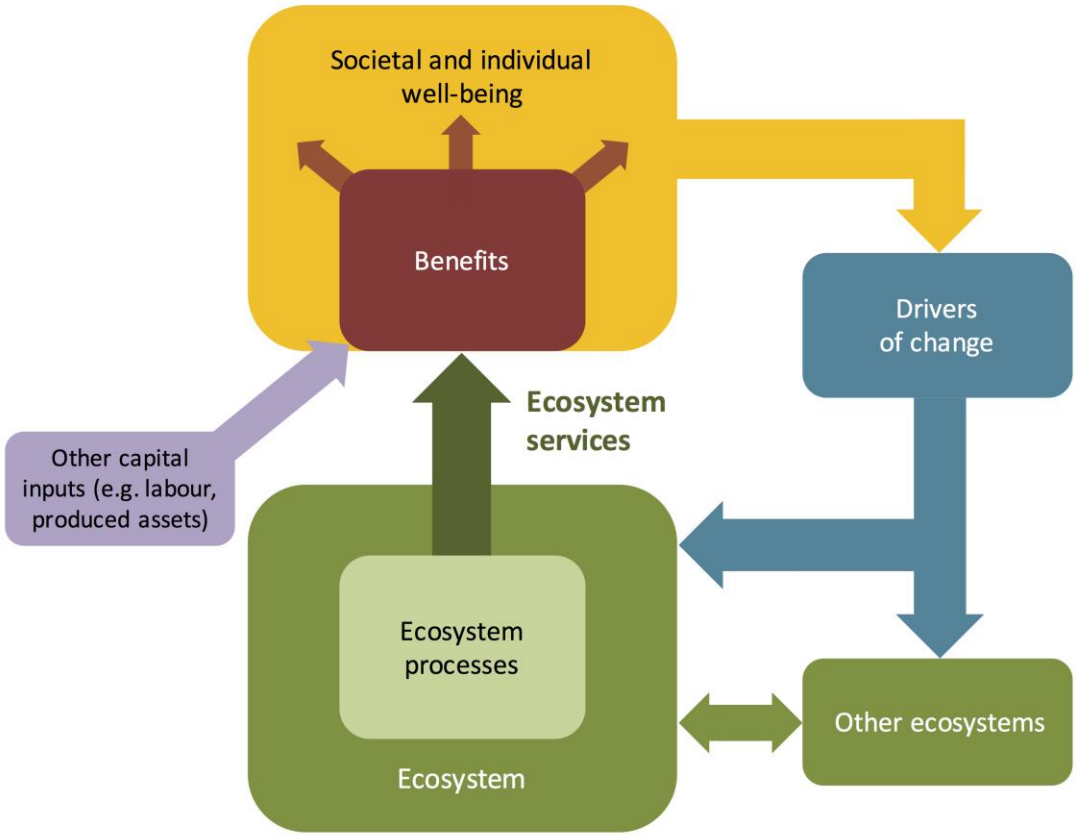
This section presents an overview of the conceptual framework that links ecosystems, ecosystem services and human well-being. It draws primarily from the very detailed discussion on ecosystem services provided in the SEEA-EEA[13]. A graphical representation of this conceptual framework is presented in Figure 1, and this is further elaborated below.

Ecosystems are defined in the Convention on Biological Diversity as "*a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional*

[10] Haines-Young and Potschin, 2010
[11] UN, 2014
[12] The SEEA definition differs slightly from that adopted in the MA, as it distinguishes ecosystem services as a flow rather than a final output. This distinction helps to better conceptualise the links between ecosystems and their services and human well-being, as presented in Section 2.2.
[13] UN, 2014

unit"[14]. Ecosystems ultimately contribute to improvements in individual and social wellbeing as a result of the benefits that are derived from ecosystem services.

Figure 1: A conceptual framework of how ecosystems and ecosystem services affect human well-being



Source: Adapted from Figures 2.1 and 2.2 of the SEEA-EEA (UN, 2014) and Figure 2.1 of the UK NEA Conceptual Framework and Methodology (Mace and Bateman, 2011).

Ecosystem services are generated through ecosystem processes, which reflect a combination of ecosystem characteristics and intra- and inter-ecosystem flows[15], in conjunction with human engagement with the environment[16]. SEEA presents three categories of ecosystem characteristics:

1. Ongoing operation: this includes its structure (e.g. the food web within the ecosystem); composition (including living and non-living components); processes (e.g. photosynthesis); and functions (e.g. recycling of nutrients in an ecosystem).
2. Location: this includes the extent of the ecosystem; its configuration (i.e. the way in which the various components are arranged and organised within the ecosystem); landscape forms

[14] https://www.cbd.int/convention/articles/default.shtml?a=cbd-02.
[15] Inter-ecosystem flows are represented in Figure 1 by the double-ended arrow between the *Ecosystem* and *Other ecosystems* blocks.
[16] Based on the definition for ecosystem services provided in SEEA-EEA, ecosystem services only exist where there is human interaction with the environment. SEEA-EEA (p63) provides an example: "*air filtration by vegetation is only realized as an ecosystem service if there is air pollution in the atmosphere that the vegetation is absorbing and if there are people living nearby that benefit from a lower concentration of air pollutants.*"

(e.g. mountain regions, coastal areas) within which the ecosystem is located; and climate and associated seasonal patterns.

3. Biodiversity: to include within and between species biodiversity, and the diversity of ecosystem types.

That ecosystem processes are also noted as an aspect of ecosystem characteristics serves to illustrate that these individual characteristics are not self-contained, but rather mutually dependent. When these dependencies relate to other characteristics within the ecosystem, they are represented by intra-ecosystem flows (such as nutrient processes), and when they are related to characteristics from another ecosystem they are represented by inter-ecosystem flows (such as seed dispersal or the transportation of water from one ecosystem to another). Consequently the type and volume of ecosystem services generated by a particular ecosystem depends on the characteristics of that ecosystem in conjunction with relevant inter-ecosystem flows.

The services derived from ecosystems subsequently contribute to benefits, and are therefore represented in Figure 1 as a flow by the arrow from the *Ecosystem processes* block to the *Benefits* block. These benefits can be defined as *material or non-material outputs that are ultimately used and enjoyed by people*[17]. The distinction between material and non-material benefits relates to those that fall within the System of National Accounts (SNA), and consequently correspond to the production boundary used to measure GDP, and those that do not. A particular distinction between these two types of benefits is that, in general, material benefits can be traded in markets whereas non-material benefits cannot[18]. Benefits may be derived directly from ecosystem services (for example clean air), or may need additional capital inputs, such as labour or machinery, for their production (for example the production of beef for human consumption from cattle), as illustrated in Figure 1.

It is ultimately these benefits that affect human well-being. This report does not attempt to give a universal definition of well-being[19], nor does it try to capture all the ways in which benefits contribute to the various components of well-being. It is however recognised that people value benefits for different reasons and in different terms. The UK National Ecosystem Assessment (UK NEA) for example explored health values and shared social values in addition to economic values[20].

The interactions between humans and ecosystems that contribute to individual and societal well-being can also impact on the characteristics of ecosystems; this can in turn affect the ability of ecosystems and their processes to generate ecosystem services in both the present and the future. This feedback is represented in Figure 1 by flows through the 'drivers of change' box. Drivers of change are discussed in greater detail in Section 3.2.3.

[17] Definition adapted from SEEA-EEA (p152).
[18] SEEA-EEA briefing note p7.
[19] Indeed the UK NEA notes that it is questionable if this is actually possible (Chapter 2, p20).
[20] Mace and Bateman, 2011

3 Methodology

The overall approach to developing an inventory of ecosystem services in Namibia draws from a number of key documents. The UK NEA was the first national level MA-style assessment, identifying UK ecosystems, their services and trends in their delivery, and is therefore a very important guiding reference. It also represents an example of a scoping study for undertaking a TEEB Country Study[21], and consequently by following a broadly similar approach this report can provide the basis for the main study phase of a TEEB Country Study. The inventory also draws on many of the concepts and definitions provided by the SEEA-EEA, which presents a comprehensive framework for ecosystem accounting, and can also help to ensure consistency with environmental-economic accounting initiatives of the ResMob project and MET.

There were five distinct steps undertaken in developing an inventory of ecosystem services in Namibia: identifying and delineating ecosystem zones; conducting an assessment of these ecosystem zones; identifying ecosystem services; developing of an inventory of ecosystem services; and prioritising ecosystem services. These steps are discussed in this section in turn.

3.1 Identification and delineation of ecosystem zones

Namibia was divided into 13 terrestrial and 4 marine zones to provide a framework for the description and analysis of ecosystem services. The ecosystem zones are depicted in Figure 2. Marine zones were delineated mainly on the basis of bathymetric regions which are characterised by distinctive communities of marine phytoplankton and fauna and economic activities. Existing boundaries and names of detailed soil and vegetation units provided an initial basis for selecting potential terrestrial zones[22]. The soil and plant community units were then merged and adjusted into ecosystem zones using several considerations.

Firstly, the number of zones was to be manageable. Secondly, the boundaries, names and general characteristics were to be familiar or identifiable to non-ecologists with a reasonable knowledge of Namibia. Thirdly, each zone was to be comprised of distinctive and reasonably homogenous physical features and ecological processes, particularly those having major impacts on resource uses, and on vegetation, animal, and human communities. Finally, the definition of ecosystem services delivered by each zone had to be viable, especially with regard to the availability of information and significance of ecosystem services (see Sections 2.2 and 3.2). Emphasis was thus placed on identifying zones that met these criteria: manageability, familiarity and knowledge, and ecological distinctiveness. This approach is justified in such an expanse as Namibia where literally hundreds of areas with separate, integrated ecological functioning, i.e. ecosystems, could be identified.

Most ecosystem zones covered contiguous areas, exceptions being the North-Eastern Rivers, Succulent Karoo and Urban zones. Urban areas are enumeration areas categorised as urban or peri-urban for Namibia's 2011 census. Land resource units and biological and human communities are extremely distinct in urban areas. This ecosystem zone is also growing substantially and rapidly: an estimated 43% of Namibians lived in urban areas (approximately 910,000) in 2011, compared to 33%

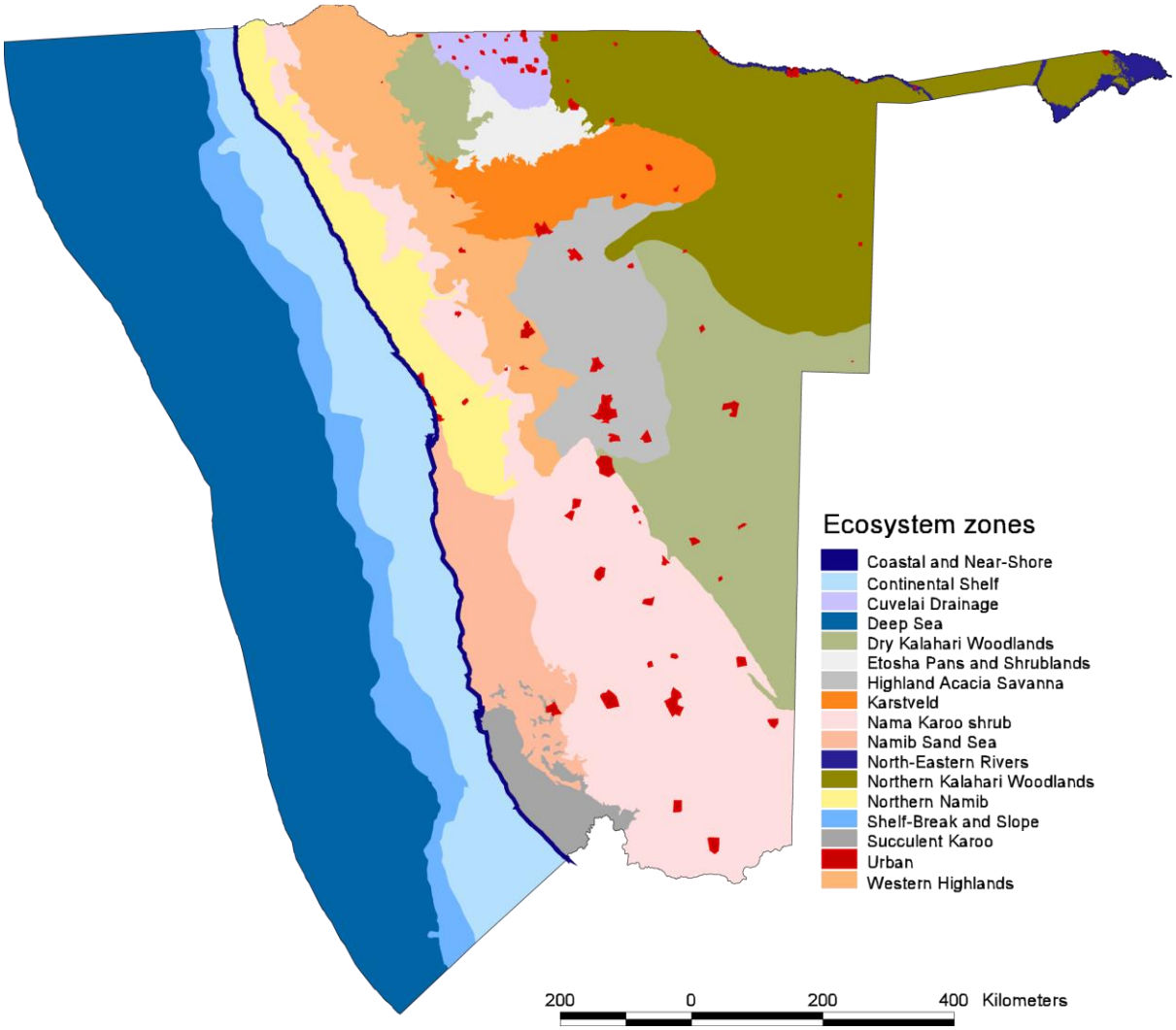
[21] TEEB, 2013
[22] EU maps, Giess, Mendelsohn et al

(605,000) in 2001. As of 2016, over half (52%) of Namibia's population is in the Urban ecosystem zone.

3.2 Assessment of ecosystem zones

An assessment of each ecosystem zone is provided, comprising of three sub-sections: main attributes and ecological processes; human activity and population; and drivers of change. The main aim of the assessment is to facilitate a better understanding of each ecosystem zone, and consequently to provide the basis for developing an inventory of ecosystem services for each ecosystem zone. Each of the three sub-sections is discussed in turn below.

Figure 2: Ecosystem zones delineated for purposes of this assessment of ecosystem services



3.2.1 Main attributes and ecological processes

The information contained in the *main attributes and ecological processes* sub-section broadly corresponds to a description of the ecosystem characteristics as defined in the SEEA (see Section 2.2). Consequently this sub-section includes a discussion of the location of each ecosystem zone; its extent; an overview of its ongoing operation, focusing on the main aspects of the structure, composition and/or functioning of the ecosystem zone; and an indication of species diversity in the ecosystem zone. Where relevant, a brief discussion of its interaction with other ecosystem zones is also provided (i.e. inter-ecosystem flows); but a more comprehensive overview of the interactions between ecosystem zones and ecosystem services is provided after the inventory has been developed (see Section 3.4).

3.2.2 Human activity and population

Ecosystem services are a consequence of human engagement with the environment (see Section 2); consequently an estimate of human populations in an ecosystem can provide a starting point from which to assess the scale of beneficiaries from, and potentially demand for, the ecosystem's services. The *human activity and population* sub-section therefore includes estimates of rural population densities and sizes of urban centres in the ecosystem zone, based on 2011 census data, as well a comparison to data from 2001 to illustrate changes in these populations. Where possible, indications of socio-economic characteristics and estimates of household poverty and annual consumption from the National Household Income and Expenditure Survey (NHIES)[23] are provided; this includes the incidence of household poverty and estimates of annual income and consumption where available.

Different types of land tenure and management affect how humans can interact with a given ecosystem zone, and consequently the ecosystem services they can derive benefits from. The description of each ecosystem zone therefore includes an overview of whether it is primarily private or communal land, as well as whether there are protected areas (including state protected areas such as National Parks, conservancies[24] and community forests[25]) within the ecosystem zone.

3.2.3 Drivers of change

Drivers of change are any natural or human-induced factor that causes ecosystem change. They can be direct or indirect: direct drivers have an explicit effect on ecosystems, usually causing some physical change that can be identified and monitored, while indirect drivers operate through their effects on the direct drivers[26]. The indirect drivers of change identified in the UK NEA were: demographic changes; economic growth; socio-political changes; cultural and behavioural changes; and advances in science and technology. These in turn influence the five direct drivers of change: habitat change; overexploitation of terrestrial, marine and freshwater resources; nutrient

[23] NSA, 2012

[24] Communal conservancies are areas of communal land in which local communities have rights over the sustainable use of wildlife, and can derive direct and indirect benefits from tourism (consumptive and non-consumptive) and other wildlife-based activities.

[25] Community forests are areas of communal land for which local communities have obtained the rights to manage and benefits from forests, woodlands and other types of natural vegetation. In practice they do not only cover forested and wooded areas, but in some cases encompass much more arid areas of desert to give communities rights over particular plants and vegetation in those areas.

[26] UK NEA, Chapter 3

enrichment and pollution of air, land and water; introduction of invasive alien species; and variability and change in climate.

This report adopts 6 drivers of change that broadly follow those identified in the UK NEA and fit within the context of Namibia's Second National Biodiversity Strategy and Action Plan (NBSAP2)[27]. A comparison between the UK NEA direct drivers of change and the broad categories adopted in this report is presented in Table 1; the main difference between the two is the addition of 'illegal use' to the drivers of change included in this report. Although illegal use represents a form of exploitation, the 'Illegal harvesting and trade of wildlife and forest and plant resources' is identified as a critical threat to biodiversity in Namibia's Second NBSAP and the appropriate policy responses to address it are likely to be quite distinct; consequently it is given a separate category.

Table 1: UK NEA direct drivers of change and broad drivers of change adopted in this report

UK NEA direct driver of change	Broad driver of change adopted in this report	Relevant 'critical threats' identified in NBSAP2	Notes
Habitat change	Habitat change	Expansion of urban areas and increasing industrialisation; rapid expansion of mining and prospecting; unsustainable land management practices; uncontrolled bush fires; human-wildlife conflict	None
Overexploitation of terrestrial, marine and freshwater resources	Exploitation	Unsustainable water uses	Some use or harvesting of the resource may be changing flows of ecosystem services, but this use or harvesting may be sustainable[28].
Nutrient enrichment and pollution of air, land and water	Pollution	Unsustainable water uses; expansion of urban areas and increasing industrialisation; rapid expansion of mining and prospecting; unsustainable land management practices;	Simplification of UK NEA terminology
Introduction of invasive alien species	Invasive species	Alien invasive species	None
Variability and change in climate	Climate change	Threats and impacts of climate change	None
N/A	Illegal use	Illegal harvesting and trade of wildlife and forest and plant resources	'Illegal use' added as poaching and illegal harvesting of resources are of much greater relevance in Namibia.

[27] MET, 2015
[28] Overexploitation refers to instances where harvesting rates exceed those of reproduction or replenishment. In some cases, current or historical rates of exploitation may represent overexploitation; this will be stated as appropriate.

For each ecosystem zone, specific examples of these drivers of change are given. Table 2 provides examples of specific pressures that may be experienced at the ecosystem-level alongside the broad classification of drivers that are relevant at the national level. The ecosystem-level drivers will be discussed in more detail in each of the relevant ecosystem zone chapters, but as an example it can be seen that habitat change may be occurring in ecosystem zones as a result of overgrazing, while illegal use may be occurring as a result of poaching.

There may be some overlap between the different categories of drivers of change; for example habitat change as a result of overgrazing could potentially also be thought of as the overexploitation of rangelands. Furthermore, where there are interactions between ecosystem services, the effect of a driver of change on one ecosystem service could ultimately represent a different driver of change on a second ecosystem service. This is discussed further in Section 3.4 and the individual ecosystem zone sections where appropriate.

Table 2: Broad drivers of change and ecosystem-specific pressures (example)

Broad driver of change	Ecosystem-specific pressures
Habitat change	e.g. overgrazing
Exploitation	e.g. abstraction of groundwater
Pollution	e.g. contamination by industrial effluents
Invasive species	e.g. *Prosopis* in river beds
Climate change	e.g. changes in patterns of precipitation
Illegal use	e.g. poaching

The drivers of change considered in this report are all anthropogenic in nature. Non-anthropogenic drivers of change are not particularly relevant in Namibia, and even in countries where they are causes of change (for example natural phenomena such as volcanic eruptions), they are generally unpredictable or only have impacts on the ecosystem zone over a very long timeframe.

The focus on direct drivers of change in this report ensures that the linkages between the drivers and the ecosystem services are conceptually relatively easy to understand. However by only considering direct drivers, policy responses to address issues based on this information may only address the symptoms and not the underlying causes. As the design of policy responses is beyond the scope of this report it is not a major concern, but is something to be considered for future uses of the report.

An explicit attempt to assess the condition of each ecosystem zone is not made in this report. The SEEA-EEA defines the condition of an ecosystem as reflecting "*the overall quality of an ecosystem [...] in terms of its characteristics*"[29]. The condition of an ecosystem can subsequently be assessed by selecting appropriate characteristics and indicators of changes in those characteristics, and relating these indicators to a common reference condition or benchmark, as the condition of an ecosystem is relative in nature. Consequently an overview of the characteristics of the ecosystem zone and the drivers of change, as discussed in this section, can provide the basis for evaluating the condition of

[29] p22.

an ecosystem zone, but a complete assessment requires more detailed analysis and is outside the scope of this report.

3.3 Identification of ecosystem services

Ecosystem services are identified and categorised at the level of each individual ecosystem zone. The CICES is adopted as the basis for this identification as the most comprehensive of the classification systems. An added benefit of using CICES is that it is incorporated into the SEEA-EEA[30], and consequently would promote consistency with potential future initiatives to undertake ecosystem accounting.

An ecosystem service is identified within a given ecosystem zone only if the point of interaction between humans and ecosystems occurs within that zone. An implication of this is that only ecosystem services for which the point of interaction between humans and ecosystems occurs in Namibia are included at the level of the whole inventory. This is necessary in order to maintain the focus on Namibia, and keep the scope of the overall inventory manageable. However, all the North-eastern Rivers which comprise the ecosystem zone of that name first flow into then out of Namibia. Certain human interactions with these rivers upstream and inside Namibia have significant downstream impacts.

CICES defines three categories of ecosystem services: provisioning; regulation and maintenance; and cultural. Each of these three categories is then further disaggregated into divisions, groups, and classes; examples of specific ecosystem services that relate to the class level are provided. Each category of ecosystem services is dealt with in turn in the sub-sections below; definitions used in this section are taken from Haines-Young and Potschin (2013) unless stated otherwise.

3.3.1 Provisioning services

Provisioning services are "*all nutritional, material and energetic outputs from living systems*". The nutritional and material divisions are disaggregated into groups that distinguish those arising from biological materials (biomass) and water, while for energetic outputs there is a distinction between biomass-based energy sources and mechanical energy. Table 3 illustrates the breakdown of provisioning services.

[30] The SEEA-EEA adopts a slightly different version of CICES than the one that is described and used in this report; this is discussed in greater detail in Section 3.3.4.

Table 3: Provisioning services in CICES

Division	Group	Class	*Examples*
Nutrition	Biomass	Cultivated crops	*Cereals, vegetables, fruits etc.*
		Reared animals and their outputs	*Meat, dairy products, honey etc.*
		Wild plants, algae and their outputs	*Wild berries, fruits*
		Wild animals and their outputs	*Game, fish*
		Plants and algae from in-situ aquaculture	*In situ seaweed farming*
		Animals from in-situ aquaculture	*In-situ farming of fish*
	Water	Surface water for drinking	*Collected precipitation for drinking*
		Groundwater for drinking	*Freshwater abstracted from (non-fossil) groundwater layers for drinking*
Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	*Wood, timber, skin which are not further processed; material for production e.g. devil's claw*
		Materials from plants, algae and animals for agricultural use	*Materials for fodder and fertilizer in agriculture and aquaculture*
		Genetic materials from all biota	*Genetic material (DNA) from wild plants, for biochemical industrial and pharmaceutical processes e.g. medicines*
	Water	Surface water for non-drinking purposes	*Collected precipitation for domestic, agricultural and/or industrial use*
		Groundwater for non-drinking purposes	*Freshwater abstracted from (non-fossil) groundwater layers for domestic, agricultural and/or industrial use*
Energy	Biomass-based energy sources	Plant-based resources	*Wood fuel, straw for burning and energy production*
		Animal-based resources	*Fat, oils, from animals for burning and energy production*
	Mechanical energy	Animal-based energy	*Physical labour provided by animals*

3.3.2 Regulation and maintenance services

Regulation and maintenance services "*cover all the ways in which living organisms can mediate or moderate the ambient environment that affects human performance*". There are consequently three major divisions of regulation and maintenances services: the mediation of waste, toxins and other nuisances; the mediations of flows; and the maintenance of physical, chemical and biological conditions. The various groups and classes that relate to these divisions are presented in Table 4.

Table 4: Regulation and maintenance services in CICES

Division	Group	Class	*Examples*
Mediation of waste, toxins and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	*Bio-chemical detoxification/decomposition/ mineralisation in land/soil, freshwater and marine systems*
		Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	*Biological filtration/sequestration/storage/ accumulation of pollutants in land/soil*
	Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	*Bio-physicochemical filtration/sequestration/storage/accumulation of pollutants in land/soil*
		Dilution by atmosphere, freshwater and marine ecosystems	*Bio-physical-chemical dilution of fluids, wastewater in lakes, rivers, sea*
		Mediation of smell/noise/visual impacts	*Visual screening of transport corridors e.g. by trees*
Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	*Erosion protection*
		Buffering and attenuation of mass flows	*Transport and storage of sediment by rivers*
	Liquid flows	Hydrological cycle and water flow maintenance	*Capacity of maintaining baseline flows for water supply and discharge*
		Flood protection	*Flood protection by appropriate land coverage*
	Gaseous/air flows	Storm protection	*Natural or planted vegetation serving as shelter*
		Ventilation and transpiration	*Natural or planted vegetation that enables air ventilation*
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	*Seed dispersal by insects, birds and other animals*
		Maintaining nursery populations and habitats	*Habitats for plant and animal nursery and reproduction*
	Pest and disease control	Pest control	*Pest and disease control e.g. invasive alien species*
		Disease control	*In cultivated and natural ecosystems and human populations*
	Soil formation and composition	Weathering processes	*Maintenance of bio-geochemical conditions of soils*
		Decomposition and fixing processes	*Maintenance of bio-geochemical conditions of soils by decomposition of dead organic material*
	Water conditions	Chemical condition of freshwaters	*Maintenance of chemical composition of freshwater column*
		Chemical condition of salt waters	*Maintenance of chemical composition of seawater column*
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*Global climate regulation by greenhouse gas/carbon sequestration by terrestrial ecosystems*
		Micro and regional climate regulation	*Maintenance of rural and urban climate and air quality and regional precipitation/temperature patterns*

3.3.3 Cultural services

Cultural services "*cover all the non-material, and normally non-consumptive, outputs of ecosystems that affect physical and mental states of people*". The cultural category can be problematic as a result of the way the terminology is used; there is often not a clear distinction between services and benefits (see Section 2.2). Consequently CICES suggests that cultural services are primarily regarded as "*the physical settings, locations or situations that give rise to changes in the physical or mental states of people, and whose character are fundamentally dependent on living processes*".

Two divisions of cultural services are specified: physical and intellectual interactions with ecosystems and land-/seascapes; and spiritual, symbolic and other interactions with ecosystem and land-/seascapes. The detailed breakdown of cultural services is presented in Table 5.

Table 5: Cultural services in CICES

Division	Group	Class	*Examples*
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	*In-situ whale and bird watching, snorkelling, diving etc.*
		Physical use of land-/seascapes in different environmental settings	*Walking, hiking, climbing, recreational fishing (angling), recreational hunting*
	Intellectual and representative interactions	Scientific	*Subject matter for research*
		Educational	*Subject matter of education*
		Heritage, cultural	*Cultural heritage*
		Entertainment	*Ex-situ viewing/experience of natural world through different media*
		Aesthetic	*Sense of place, artistic representations of nature*
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	*Emblematic plants and animals e.g. Namibian Oryx, Welwitschia*
		Sacred and/or religious	*Spiritual identity; sacred plants and animals and their parts*
	Other cultural outputs	Existence	*Enjoyment provided by wild species, wilderness, ecosystems, land-/seascapes*
		Bequest	*Willingness to preserve plants, animals, ecosystems, land-/seascapes for the experience and use of future generations*

3.3.4 CICES, final ecosystem services and double-counting

CICES makes clear that it focuses on final ecosystem services, which as noted in Section 2.1 represent the point of interaction between humans and ecosystems. This distinction is important to avoid double-counting in the contribution of ecosystem services to benefits. Indeed, the SEEA-EEA recognises that "*ecosystem services…should be measured only when SNA or non-SNA benefits can be identified*".

However it is not necessarily possible to identify the benefits for each of the ecosystem services within the CICES framework. One example can be seen in the presence of separate provisioning ecosystem service classes of *reared animals and their outputs* (e.g. meat) and *surface water for non-drinking purposes* (e.g. water for livestock), where the latter can clearly represent an input to the former. Consequently the ultimate benefit derived from the provisioning service of water for livestock in this example is realised when it is used to produce meat, and taking them individually would double count the ultimate contribution of ecosystem services to benefits.

In order to avoid this issue of double-counting, the version of CICES adopted by SEEA is slightly different to that presented in this report. Instead of recognising the amount of meat or crops harvested as the ecosystem service with respect to reared animals or cultivated crops (the 'harvest approach'), it classifies as ecosystem services the flows related to nutrients, water and various regulating services (e.g. pollination) that contribute to their growth. The alternate version of CICES adopted by SEEA and a more detailed discussion can be found in SEEA-EEA p50.

Despite not being able to identify a direct and final contribution to a distinct benefit for each ecosystem service, this report maintains the full classification of CICES (as detailed in Table 3 – 5); it represents the most recent version of CICES and is appropriate for the purposes of developing an inventory of ecosystem services. The version presented in SEEA is conceptually significantly more complex, and it is not clear that the certainty of avoiding double-counting is worth this added complexity.

3.4 Development of an inventory of ecosystem services

Based on the identified ecosystem services, an inventory of ecosystem services was developed for each ecosystem. The inventory contains a range of information; this includes an overview of ecosystem services by category, the estimated trends in the flow of these ecosystem services and the impacts of different drivers of change on this flow.

Table 6 provides an example of how an overview of provisioning services is presented at the level of an individual ecosystem zone. Ecosystem services are generally grouped at the 'class' level (as described in the overview of ecosystem services under CICES in Section 3.3) unless there are significant differences across services within the class with respect to the relevant population affected or the type of economic value derived. The beneficiary population gives an impression of the location of the population that benefits from the service; this is categorised as local, regional, national, international and global. As stated in Section 3.3, an identified ecosystem service must have beneficiaries in Namibia; consequently an international beneficiary population refers to beneficiaries that extend beyond Namibia and into other, most likely neighbouring, countries.

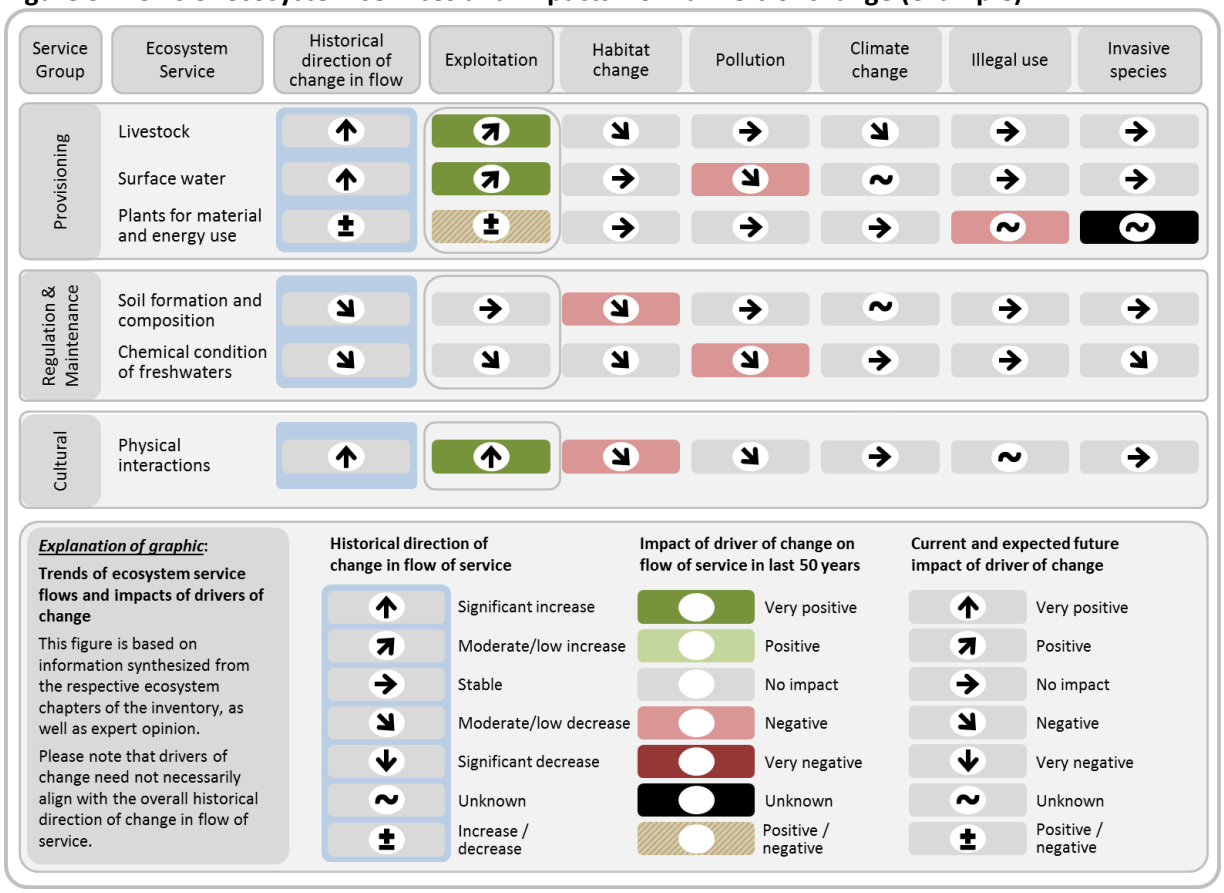
The type of economic value captures the way in which we, as humans, interact with ecosystem services, which in turn determines how we may value different ecosystem services and the benefits we derive from them. This can provide wider context to the ecosystem service, and is most useful when considering the economic valuation of ecosystem services (see the accompanying *Roadmap for the Economic Valuation of Ecosystem Services in Namibia* document (page 244)).

Table 6: Overview of provisioning services (example)

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Cultivated crops	e.g. maize	National	Consumptive Use
Reared animals and their outputs	e.g. meat and dairy products from livestock (cattle)	International	Consumptive Use
Groundwater for drinking	e.g. drinking water for urban and rural residents	Regional	Consumptive Use
Plant-based resources	e.g. wood fuel	Local	Consumptive Use

The estimated trends in the flow of each ecosystem service, and the impacts of different drivers of change on this flow, are presented graphically in the inventory; Figure 3 is an example of this graphical representation. Individual services are aggregated, usually to the class level, to allow for a concise presentation of the drivers of change and their impacts on different types of services.

Figure 3: Flows of ecosystem services and impacts from drivers of change (example)



The graphic adopts the style used in the UK NEA, with a detailed explanation of the graphic provided within the figure. The *historical direction of change in flow* column uses arrows to illustrate how the flow of the ecosystem service class is thought to have changed over the past 50 years[31], indicating

[31] A time period of 50 years was chosen primarily to provide consistency with the UK NEA and MA studies. It is also long enough to identify any trends that should be evident.

both the strength (i.e. significant, moderate) and direction (i.e. increase, decrease, stable) of the estimated change in flow; the tilde ("~") is used to denote where the change in flow is unknown. As the individual ecosystem services may have been aggregated, a ± is used to show where the flows of different services within this aggregation are thought have been impacted in opposing ways. In Figure 3, one reason for the ± sign relating to plants for material and energy use may be increased use of wood as a fuel, but decreased use of wood/timber/poles for building materials.

There are six columns which relate to each of the broad categories of the direct drivers of change: *Exploitation; Habitat change; Pollution; Climate change; Illegal use; and Invasive species*. *Exploitation* can be thought of as a primary driver of change, as it involves the direct use of ecosystem services by people. The *Exploitation* column has therefore been marked out in the graphical representation. As the remaining five drivers of change do not involve the direct use of ecosystem services, they can therefore be thought of as secondary drivers.

The colour of each box underneath these headings denotes the estimated impact of the driver of change on the ecosystem service over the past 50 years (e.g. dark green refers to a *very positive* impact; that is, the driver of change is thought to have contributed to increased flows of the ecosystem service over the past 50 years) while the arrows within the boxes illustrate the expected ongoing impact of the driver of change.

To take an example, the provision of surface water has increased significantly over the past 50 years. This is due to a very positive impact from *Exploitation* – i.e. more water has been extracted from surface water sources for use in agriculture, industry, domestically etc. However, *Pollution* has had a negative impact on the flow – i.e. it has made some surface water unsuitable for use. *Habitat change*, *Climate change*, *Illegal use*, and *Invasive species* are thought to have had no impact on the provision of surface water over the past 50 years. We expect that *Exploitation* will continue to impact positively on the flow of surface water and that *Pollution* will continue to have a negative effect into the future. However, it is unknown as to how *Climate change* will affect the service.

There are two key issues to keep in mind regarding Figure 3 and the relevant graphics in the individual ecosystem zone sections. The first is that differences in the supply and demand for services may not be well illustrated. For example, the provision of many cultivated crops is estimated to have increased significantly over the past 50 years as a result of greater exploitation to meet increased demand. However, habitat change as a result of land degradation may have had a negative impact on the ability of the ecosystem to provide the service over the same period, through a reduction in the potential yield. These opposing impacts can be reconciled if we think that the negative impact has not been large enough to reduce yields below the current level. The advantage of this decomposition is that it enables an overview of where pressures may be building, despite not impacting observable changes in flows of services.

The second issue is that ecosystem services are interlinked. Figure 3 illustrates that the provisioning services related to surface water from the rivers are thought to have increased significantly over the past 50 years, driven by increased exploitation which is expected to continue. However this continued exploitation could have negative impacts on river levels and flows, which could in turn reduce the ability of the rivers to mediate waste and pollution, or to maintain their condition.

Another example of this could be a negative feedback loop whereby the increased farming of livestock leads to increased meat production, but also results in land degradation. This land degradation in turn reduces the carrying capacity of the land, and for a given number of livestock, could result in lower meat production in the future. These linkages will be discussed in greater detail in the individual ecosystem zone sections.

3.5 Prioritisation of ecosystem services

In order to assist with mainstreaming ecosystem services in policy and decision making (both public and private), it is necessary to focus on certain key ecosystem services in more detail. This section lists five criteria that are applied to prioritise ecosystem services for mainstreaming. The criteria are based on three thematic blocks identified for prioritisation in the SEEA-EEA; Table 8 illustrates how these criteria are linked to the thematic blocks. It should be noted that the *Availability of data* criterion should only be applied to ecosystem services identified in the other four criteria, and consequently should be seen as a supplementary decision aid. This is further elaborated below.

Table 8: Suggested prioritisation criteria for ecosystem services and SEEA-EEA thematic blocks for prioritisation

Prioritisation criteria	SEEA thematic block
Current and expected future impacts on the flow of the service	Environmental concerns
Services affected by critical threats identified in NBSAP2	
Economic importance (current and potential)	Policy context
Affected population (size and socio-economic characteristics)	
Availability of data	Data and methods

Ecosystem services that are relevant to each criterion are first identified at the ecosystem zone level, and then summarised at the national level. The five criteria are briefly discussed below. There are of course limitations to prioritising individual ecosystem services; the main concern is that it ignores the interactions between ecosystem services, and the mainstreaming of ecosystem services into policymaking needs to incorporate precisely these interactions to ensure that policies are as appropriately designed as possible. For each ecosystem zone, an overview of interactions between ecosystem services both within that ecosystem zone and between that ecosystem zone and other ecosystem zones is provided.

Current and expected future impacts on the flow of the service

The *current and future expected impacts on the flow of the service* criterion assesses which ecosystem services are facing the greatest threats.

Services affected by critical threats identified in NBSAP2

Nine critical threats to biodiversity were identified in NBSAP2. This criterion highlights those ecosystem services that are most under pressure from these threats.

The critical threats are:

1. Unsustainable water uses;
2. Expansion of urban areas and increasing industrialisation;
3. Threats and impacts of climate change;
4. Rapid expansion of mining and prospecting;
5. Unsustainable land management practices;
6. Uncontrolled bush fires;
7. Alien invasive species;
8. Illegal harvesting and trade of wildlife and forest and plant resources; and
9. Human-wildlife conflict.

As NBSAP2 has been passed by parliament, prioritising ecosystem services with respect to the nine critical threats identified within it also falls under the policy context because it presents an opportunity to connect the prioritisation process to the policymakers' agenda.

Economic importance (current and potential)

Ecosystem services are prioritised within this criterion with regard to their contribution to the economy, which could be at a national or a local level. It also includes those services that have the potential to be of significant economic importance if restored or managed in an appropriate manner.

Affected population (size and socio-economic characteristics)

This criterion prioritises ecosystem services based on their affected population. This takes account of both the size of the population (i.e. number of people affected), as well as their socio-economic characteristics (i.e. prioritising those services that affect the poorest in society).

Availability of data

This criterion identifies those ecosystem services for which data surrounding the flow of the ecosystem service is likely to be easily available. It can therefore be used to highlight those ecosystem services identified in the previous four criteria that could be subject most quickly and easily to more detailed studies to assist with their mainstreaming. However these should not be the only services that are prioritised for mainstreaming, as they will primarily be a limited selection of provisioning services. Furthermore, the deficiency of data for some services should also be seen as a reason to focus further studies on them, as collecting such data would be incredibly valuable.

3.6 References

De Pauw, E, and Coetzee, M.E. (1998/99). Production of an agro-ecological zones map of Namibia (first approximation) - Part I: Condensed Methodology. Agricola 10: 27-31.

De Pauw, E, Coetzee, M.E, Calitz, A.I, Beukes, H, and Vits, C. (1998/1999). Production of an agro-ecological zones map of Namibia (first Approximation) - Part II: Results. Agricola 10: 33-43.

European Commission Joint Research Centre (2013), Soil Atlas of Africa, <http://eusoils.jrc.ec.europa.eu/library/maps/africa_atlas>

GIESS, W., (1998). A Preliminary Vegetation Map of Namibia. Dinteria 4: 1–112.

Mendelsohn JM, Jarvis AM, Roberts CS and Robertson T. (2002). Atlas of Namibia. David Philip, Cape Town. 200 pp.

4 Key ecosystem processes

This section describes major ecological processes in Namibia, many of which have substantial impacts on the functioning of several ecosystem zones.

4.1 Climate change

Climate change is widely regarded as a major driver of change. Substantial changes to Namibia's climate are anticipated and many of the details have become rooted in dogma. For example, while it is accepted that temperatures and sea levels have risen, further increases in these parameters can only be projected. Claims that rainfall patterns and extreme events such as flooding and droughts have changed as a result of climate change are now regarded as fact, although supporting evidence is circumstantial at best. Almost every report on climate change repeats the prediction that Namibia's climate will become more variable but again, evidence to support this prediction is lacking. If anything, the projected increase in the extent of the Southern Ocean as result of ice melting and greater stability of the South Atlantic Anticyclone suggests that southern Africa's climate may become more stable.

Comments in this report on anticipated changes to ecosystem services are therefore necessarily cautious. This is not to downplay the importance of climate change as a general driver of change, but rather to err on the side of scientific probability than doctrine. A cautious objective approach also lends greater credibility to projections and debate about climate change.

4.2 Fire

Much of Namibia is a mosaic of grassland and woodland – broadly called savannas – which are largely formed and moulded by bush fires. Burning, especially by hot fires, limits the growth of trees, allowing greater expanses of grassland to develop amongst the trees. Conversely, trees and bush are dense in areas that seldom burn, or are only burnt by cool fires.

The frequency and intensity of bush fires are also affected by rainfall through its impact on plant production and therefore fuel. Livestock density and land clearing have opposite effects. Little dry plant material is available to fuel fires in the most arid, or heavily grazed or cleared areas, while the opposite is true where grass is abundant as a result of substantial rain and/or limited grazing and land clearing.

There are two broad fire zones in Namibia. The first is in communal areas in the north and east, largely in the Northern Kalahari Woodlands and the eastern half of the Dry Kalahari Woodlands. Rainfall is relatively high and there are large areas of woodland that support few cattle and fields in this fire zone. Some of the areas burn intensely almost every year, usually towards the end winter when grass fuel is dry and winds are strong. The great majority of these fires are set by local residents, and the frequency of very hot fires may have increased, perhaps as a result of greater numbers of people. The main effect of frequent hot fires has been to convert large areas of tall, climax woodland into *Baphia* and *Bauhinia* shrubland. Paradoxically, these changes are particularly evident in protected areas where there are few cattle, such as Bwabwata National Park and the Caprivi State Forest.

The second zone is in central Namibia on freehold farms, largely in the Karstveld, Highland Acacia Savanna, and the freehold areas of the Northern Kalahari Woodlands and the Dry Kalahari

Woodlands. Fires are very infrequent in this central area, some farms having escaped burns for decades. The fires are often cooler because of sparser grass cover, which is due to lower rainfall and intense grazing by cattle. The presence of many fire breaks and immediate measures to extinguish fires also reduces the frequency of fires.

The wettest areas of this central non-burning area now support high densities of woody plants, and this is where bush encroachment has been most severe.

There are also examples of areas of very dense bush in the first zone of communal land. These are all in places which seldom burn as a result of management practices, such as Mangetti National Park, Mangetti Namibia Development Corporation (NDC) farms, Mile 46 Cattle Farm in Kavango West and Sachinga Cattle Farm in Zambezi.

4.3 Bush encroachment

Bush encroachment is defined as "the invasion and/or thickening of aggressive undesired woody species resulting in an imbalance of the grass:bush ratio, a decrease in biodiversity, and a decrease in carrying capacity"[32]. It affects an estimated 26 to 30 million hectares of land in Namibia.

Bush encroachment is largely a direct or proximate consequence of an absence of fire in the central and northern areas of Namibia. Indirectly however, commercial livestock farming and high stocking rates are the dominant ultimate causes of bush encroachment because they limit the occurrence of hot fires which kill woody plants.

Fire may have little impact on bush encroachment in the more arid southern and western areas of the country. Here, severe grazing pressures by sheep, cattle and goats may be the proximate cause of increased bush cover and densities. A reduction in competition from grass for nutrients and water leading to more vigorous bush growth is the likely mechanism. The additional water and nutrients left in the soil are then taken up by bushes, fuelling their growth at the expense of grass growth.

Rainfall also contributes to bush growth and thickening, growth rates being directly correlated with precipitation. Other processes thought to contribute to bush encroachment are increased temperatures, higher atmospheric carbon dioxide levels, and the displacement of browsers, such as kudu, by cattle or other grazing livestock, which puts extra pressure on the grassy component and relieves pressure on the woody plants which flourish

Bush encroachment has negative, and sometimes substantial, impacts on ecosystem services that are of significant value to Namibia. Recent research indicates that bush encroachment probably reduces groundwater recharge rates in many areas of Namibia. This is primarily as a result of soil capping (which leads to greater surface run-off) and the uptake of shallow water by woody plants. Bush encroachment also reduces livestock carrying capacity via reduced grass cover. Dense bush reduces opportunities for tourism activities, such as wildlife viewing and hunting, and is thought to impact biodiversity.

[32] De Klerk 2004

4.4 Changes from livestock to wildlife farming

Most freehold farms were originally established to produce livestock products, generally milk, beef and mutton. Options broadened when legislative changes in the 1970s gave freehold farmers economic rights over wildlife, allowing them to profit from sales of live game, game meat and trophy hunting. A substantial increase in foreign tourism to Namibia in recent decades created further incentives for freehold farmers to use their land for tourism as well.

As a result of these changes, economic returns from farmland have diversified and large areas of natural vegetation on freehold farmland are now maintained for their value in producing wildlife and tourism revenue.

4.5 Cattle ownership in communal land

While cattle numbers have declined in freehold areas in recent decades, numbers in communal areas have increased substantially over the same period. For example, cattle numbers in the former Owambo communal area rose from about 300,000 in the early 1990s to over 900,000 in the last few years.

Most of these cattle are owned by businessmen and civil servants working in towns elsewhere in Namibia. The animals have largely been acquired and are maintained with income obtained from wages and business. Their main purpose is not meat or milk production, but to serve as capital assets while also justifying the acquisition of large tracts of land by their owners. Offtake rates are lowest in agro-pastoral communal areas, where they typically range between 5 and 8% per year. In pastoral communal areas, such as Kunene, offtakes usually exceed 12% and may be significantly higher in Otjozondupa and Omaheke.

4.6 Rural emigration and urban growth

Namibia is typically portrayed and viewed as a rural country where farming is the dominant land use, agriculture is the cornerstone of the economy, and the majority of people are claimed to be dependent and/or subsist on agriculture. This approximation may have been reasonable several decades ago, but the country's character has changed radically since Independence. High proportions of people born in rural areas have left, and continue to seek incomes and further education in towns as soon they leave school, which is often before the completion of secondary schooling. Rural populations have dropped in absolute terms, while many towns have grown at rates of more than 4% per year.

Urban populations are now dominated by people between the ages of 20 and 55, while most rural people are young children or are retired. Among working age people, there are significantly more women than men in rural areas. Soon after the last population census in 2011, the number of people in urban areas surpassed those in rural areas.

Rural populations' dependence on agricultural incomes – either in cash or in-kind – has also declined so that most income now comes from urban sources in the form of remittances and grants. Rural areas therefore not only support fewer people in real terms than before, they also provide less income for those who continue to live in rural areas.

4.7 Urban challenges

While Namibian towns and cities are small compared to those in most other parts of the world, the biggest urban areas have become significant sources of actual or potential pollution. Solid waste, air pollution and chemical leakages into rivers and underground water are growing concerns both within city limits and in surrounding rural areas.

Many towns now support significant populations living in informal shacks and squatter homes where they lack sewage and solid waste removal, and where many residents burn wood cut from nearby indigenous trees. Wood fires for cooking and heating produce smog which is trapped by winter temperature inversions.

Growing urban populations and particular industries and institutions (such as schools, prisons and other state services) place severe stresses on water resources and supply systems that were generally built decades ago for much lower demand. The development of all new potential supplies is accompanied by significant financial costs.

In the case of drawing water from the Okavango River, there are also political costs. The river flows through Angola, Namibia, and Botswana and drains into the Okavango Delta, a significant water source and tourist attraction for Botswana. Abstraction from and other interactions with the river can have significant downstream implications, with international impacts. The Okavango is now seen as a likely major supplier of water to Windhoek and other central towns and rural areas, as well as the Cuvelai in Namibia and Angola. However, this will involve upstream risks (e.g. if Angola increases abstraction or pollution) and downstream costs (e.g. if there is less water for Botswana to abstract or if abstraction in Namibia reduces the volume of water reaching the Delta).

4.8 References

4.8.1 Climate change

DEA (Department of Environmental Affairs). (2013). Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Trends and Scenarios for South Africa. Pretoria, South Africa.

Engelbrecht, F. A., Landman, W. A., Engelbrecht, C. J., Landman, S., Bopape, M. M., Roux, B., McGregor, J. L., and Thatcher, M. (2011) Multi-scale climate modelling over Southern Africa using a variable-resolution global model, Water SA, 37, 647–658, 2011.

Winsemius HC, Dutra E, Engelbrecht FA, Archer Van Garderen E, Wetterhall F, Pappenberger F and Werner MGF. (2014) The potential value of seasonal forecasts in a changing climate in southern Africa, Hydrol. Earth Syst. Sci., 18, 1525-1538.

4.8.2 Fire

Geldenhuys, C.J. (1977) The effect of different regimes of annual burning on two woodland communities in Kavango. South African. Forestry Journal # 103.

Humphrey G. (2015) The role of humans in the complex fire, climate and vegetation regimes of North-East Namibia. Unpublished Annual Research Report.

Joubert, D.F., Smit, G.N. and Hoffman, M.T. (2012) The role of fire in preventing transitions from a grass dominated state to a bush thickened state in arid savannas. Journal of Arid Environments, 87(2012): 1–7.

Le Roux .J (2011) The Effect of Land Use Practices on the Spatial and Temporal Characteristics of Savanna Fires in Namibia. Fridrich-Alexander-Universitat Erlangen-Nunberg, Germany. PhD Thesis 1 – 182.

Sheuyange, A., Oba, G. and Weladji, R. B. (2005) Effects of anthropogenic fire history on savanna vegetation in north-eastern Namibia. Journal of Environmental Management 75, 189–198.

4.8.3 Bush encroachment

Bester, F.V (1999) Major problem: bush species and bush densities in Namibia. Agricola 10: 1-3.

Bond, W.J., Midgley, G.F. and Woodward, F.I. (2003) The importance of low atmospheric CO2 and fire in promoting the spread of grasslands and savannas. Global Change Biology 9: 973-982.

Bond, W.J., Midgley, G.F. and Woodward, F.I. (2003) What controls South African vegetation – climate or fire? South African Journal of Botany. 69: 79-91.

Colin Christian and Associates CC. (2010) The Effect of Bush Encroachment on Groundwater Resources in Namibia: a Desk Top Study. Report for the Namibian Agricultural Union, Windhoek.

De Klerk, N. (2004) Bush encroachment in Namibia. Ministry of Environment and Tourism.

Joubert, D.F. (2014) The Dynamics of Bush Thickening by *Acacia mellifera* in the Highland Savanna of Namibia. PhD, Faculty of Natural and Agricultural Sciences, Department of Animal, Wildlife and Grassland Sciences (Grassland Science), University of the Free State, Bloemfontein, South Africa.

Joubert, D.F., Smit, G.N. and Hoffman, M.T. (2012) The role of fire in preventing transitions from a grass dominated state to a bush thickened state in arid savannas. Journal of Arid Environments, 87(2012): 1–7.

Joubert, D.F., Smit, G.N. and Hoffman, M.T. (2013) The influence of rainfall, competition and predation on seed production, germination and establishment of an encroaching Acacia in an arid Namibian savanna. Journal of Arid Environments, 91: 7–13

Mendelsohn, J.M. (2006) Farming systems in Namibia. RAISON, Windhoek.

Mendelsohn, JM. and el Obeid, S. (2005) Forests and woodlands of Namibia. RAISON, Windhoek.

Michael D. Cramer MD, van Cauter A and Bond WJ. (2010) Growth of N2-fixing African savanna Acacia Species is constrained by below-ground competition with grass. Journal of Ecology 98: 156–167.

4.8.4 Changes from livestock to wildlife farming

Directorate of Veterinary Services. Annual livestock Censuses (1970-2014) Ministry of Agriculture, Water and Forestry.

Lindsey, PA, Alexander, R, Frank, LG, Mathieson, A, & Romanach, SS (2006) Potential of trophy hunting to create incentives for wildlife conservation in Africa where alternative wildlife-based land uses may not be viable. Animal Conservation 9 (3), 283-291.

Mendelsohn, J.M. (2006) Farming systems in Namibia. RAISON, Windhoek.

4.8.5 Cattle ownership in communal land

Directorate of Veterinary Services. Annual livestock Censuses (1970-2014). Ministry of Agriculture, Water and Forestry.

Kruger B. (2014) Study on Informal Trade of Beef/Cattle in the Northern Communal Areas of Namibia. Report for Millennium Challenge Account Namibia.

Liagre, L. (2000) Cattle Marketing in Northern Namibia: A Commodity Chain Approach. NEPRU Research Report No. 20. May 2000. Windhoek.

MAWRD. (2000) Livestock Marketing in the Northern Communal Areas of Namibia (Livestock Producer Marketing Strategies and Informal Trade in Live Animals, Meat, Hides and Skins). Northern Regions Livestock Development Project (NOLIDEP);

Mendelsohn JM. (2013) Survey of Kavango Farms. Report for Ministry of Lands and Resettlement.

Vigne, P. (2001) Cattle marketing in the Epupa, Ruacana and Onesi Constituencies of the Kunene and Omusati Regions. Report to the Meat Board of Namibia, Windhoek.

4.8.6 Rural emigration and urban growth

Keyler, S. (1995) Economics of the pearl millet subsector in Northern Namibia. A summary of baseline data. International Crops Research Institute for the Semi-Arid Tropics. Working Paper 95/03.

Mendelsohn JM, Jarvis AM, Roberts CS and Robertson T. (2002) Atlas of Namibia. David Philip, Cape Town. 200 pp.

Namibia Statistics Office. (2011) Census Report.

RAISON. (2010) An atlas of Namibia's population: monitoring and understanding its characteristics. Ghost written for Central Bureau of Statistics, Namibia. 64 pp.

4.8.7 Urban challenges

Bethune, S., Griffin, M. and Joubert, D. (2004) National Review of Invasive Alien Species – Namibia. Final Report to SABSP. Directorate of Environmental Affairs Discussion Document. Windhoek.

Mapani, B.S. and Schreiber, U. (2008) Management of city aquifers from anthropogenic activities: Example of the Windhoek aquifer, Namibia. Physics and Chemistry of the Earth, Parts A/B/C, 33(8–13): 674–686.

Nickanor NNM. (2013) Food deserts and household food insecurity in the informal settlements of Windhoek, Namibia. Ph D Thesis University of Cape Town.

Pendleton W, Crush J and N Nickanor. (2014) Migrant Windhoek: Rural–Urban Migration and Food Security in Namibia. Urban Forum (2014) 25:191–205

Wamukonya. L. (1997) Study on energy consumption patterns of rural and peri-urban households in Namibia. University of California, Berkeley.

5 Namibia's ecosystem zones and their services

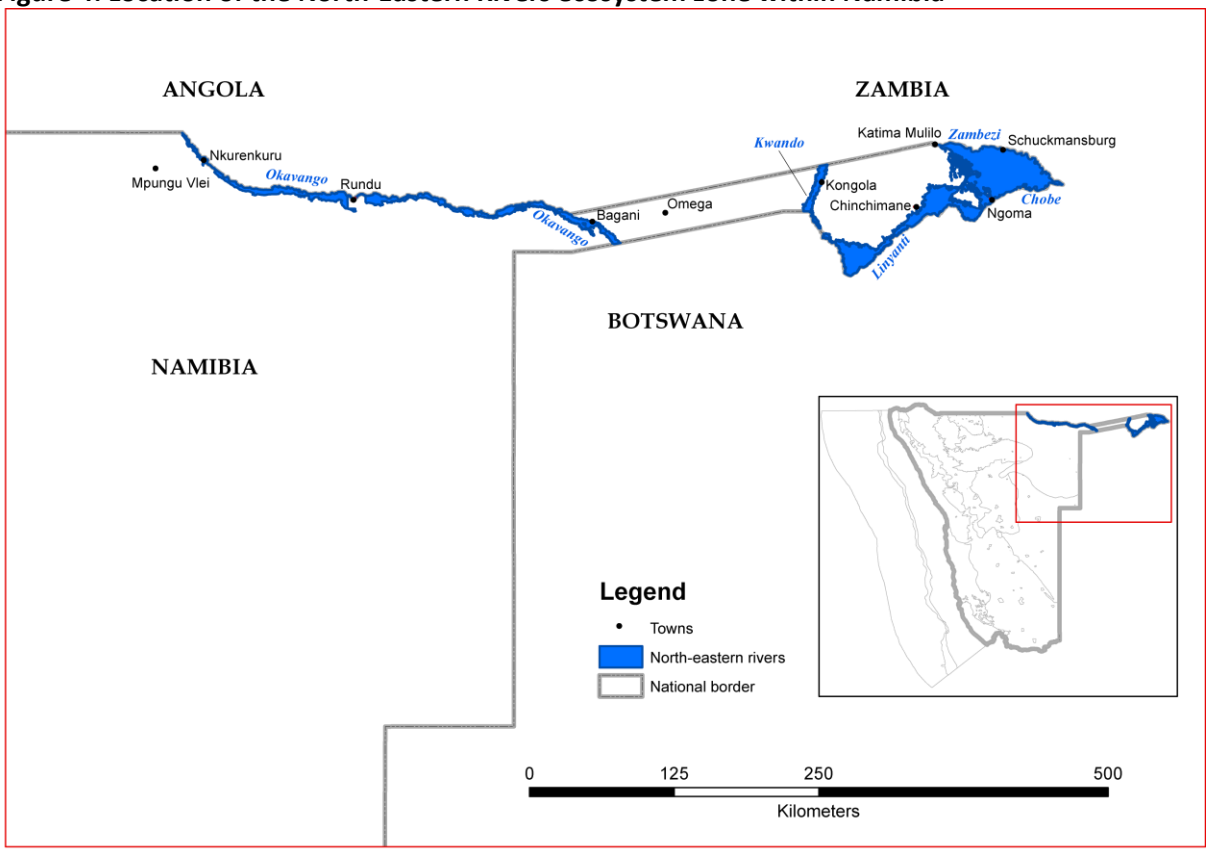
5.1 North-Eastern Rivers

5.1.1 Description and assessment of ecosystem zone

5.1.1.1 Main attributes and ecological processes

The North-Eastern Rivers (NE Rivers) ecosystem zone is delineated in Figure 4 and covers approximately 5,800 square kilometres, comprising the Okavango, Kwando/Linyanti/Chobe and Zambezi perennial rivers and their floodplains. Within Namibia, all three rivers traverse expanses of deciduous Kalahari sand woodland in which nutrients and animal biomass are very low, and where surface water is seldom available. Consequently the rivers and their floodplains function as linear oases, providing permanent supplies of water, aquatic habitats, biological resources and alluvial soils for people, animals and plants living in north-eastern Namibia.

Figure 4: Location of the North-Eastern Rivers ecosystem zone within Namibia



The three rivers are shared along borders with Angola, Zambia and Botswana as immediate neighbours, while the Zambezi holds downstream importance for Zimbabwe and Mozambique, as well as other areas of Zambia. Water in the rivers is usually clear, largely devoid of nutrients and suspended particles as a result of the predominance of sandy soils in the catchments in Angola and

Zambia. With an annual average volume of 40,000 million m^3 at Katima Mulilo, the Zambezi is much larger than the Okavango (5,200 million m^3 at Mohembo) and Kwando (915 million m^3 at Kongola)[33].

The Okavango flows along 470 kilometres of the Namibia/Angola border before crossing through Namibia into Botswana and the Okavango Delta, which has World Heritage Site Status and consequently considerable international importance. The Kwando flows into Namibia from Angola and all its water is normally deposited in the Linyanti Swamps which border with Botswana. Occasionally when river levels are particularly high, flows of Kwando water may enter Lake Liambezi, the Chobe River, and the Savuti Channel and Selinda Spillway in Botswana.

The Zambezi flows for about 150 kilometres along the Namibia/Zambia border. When water levels are high the river overtops its bank east of Katima Mulilo, distributing flood water across the eastern floodplains and down the Bukalo Channel to Lake Liambezi. The Zambezi also backs-up along the Chobe River along the Botswana border; when there is significant water in the Zambezi, flows can extend as far as the Chobe Swamps and Lake Liambezi. Water in the Chobe therefore moves 'upstream' in the summer but then reverses 'downstream' when the flow in the Zambezi reduces during the dry winter months.

Flows in all three rivers are derived from rain between October and April, with peak rainfall coming in the months of January, February and March. Water levels in the Zambezi and Okavango respond accordingly, rising in October and then gradually falling after peak flows in March and April. Water levels in the Kwando however change very slowly because of its extremely gentle gradient (about 0.5 metres per kilometre) and the clogging of its upstream course by massive expanses of reeds, papyrus and other aquatic plants. Peak levels at Kongola are consequently in July. The plants not only stem the movement of water but also filter out most nutrients and suspended particles before the Kwando reaches Namibia.

Water levels and expanses of lateral flooding vary considerably from year to year as a result of seasonal fluctuations of precipitation in their catchments; these represent only short-term changes. However there have also been much greater changes in the longer term, even to the extent that the rivers have dried up during long dry cycles or flooded much greater areas when rainfall was perhaps several times greater than at present. The biota of these rivers has thus evolved under conditions of short and long-term change.

As with the Kwando, nutrient levels in the Zambezi and Okavango are also rather low or mesotrophic. As a result, fish and other biomass are low. Most biological production occurs in floodplains or swamps that are dry for extended periods and then flood sporadically. When wetted with flood or rainwater, nutrients released from these fertile soils generate bouts of growth and reproduction among great numbers of plants and animals that range in size from tiny phyto- and zooplankton to large fish, herons, lechwe and water lilies and reeds. Lake Liambezi is extremely productive for this reason, while significant production also occurs in the Zambezi's eastern floodplains, the margins of the Linyanti Swamps and in floodplains along the Okavango in Bwabwata

[33] Calculated from discharge recordings by the Department of Water Affairs, Namibia.

National Park, around the Cuito's confluence with the Okavango and along a stretch of about 105 kilometres upstream of Rundu.

Today, the original riverine woodland is sparse or absent along most of the three rivers. However, where these riparian forests remain, they are the only places in Namibia where a variety of tropical plant and animal species occur, and thus have local biodiversity value.

The NE Rivers ecosystem zone has the greatest diversity of animal species in Namibia, and is the only place to find certain flagship species in Namibia (for example lechwe and sitatunga). It also supports significant populations of lion, leopard, wild dog, hippos, buffalo, zebra, giraffe and elephant, several of which move along corridors between Angola, Namibia and Botswana.

5.1.1.2 Human activity and population

Rundu and Katima Mulilo are the only significant commercial and service centres within a large area, and have been growing rapidly in recent decades. In 2011, Rundu was the second most populous town in Namibia, with approximately 63,000 inhabitants, while Katima had a population of approximately 28,000 in 2011. The population of Rundu is estimated to have grown by some 71% since 2001, compared to 28% for Katima Mulilo over the same time period. Along the rivers there are also a number of small (less than 5,000 residents each) towns: Katwitwi, Nkurenkuru, Kahenge, Ndiyona, Divundu and Kongola.

Rural populations in north-eastern Namibia are largely located within about 10 kilometres of these rivers; residents generally live either in houses spread along the rivers or in small villages. These rural populations are estimated to have grown from around 99,000 to 110,000 (11%) between 2001 and 2011, and represent the second densest rural populations (approximately 19 people per km^2) across the 16 rural ecosystem zones identified in Figure 2. Land parcels are allocated with usage rights to individual families, and while tenure is generally secure, significant numbers of people have been displaced by traditional authorities in Kavango. Land rights are not tradable and thus have little investment value for local residents. Most rural income is derived from social grants, remittances, wages, businesses and other off-farm sources.

As a result of the location of rural population in north-eastern Namibia, an overview of the socio-economic characteristics of these populations can be estimated by looking at the Zambezi and (to an extent) Kavango regions. These regions had the highest incidences of households in poverty and severe poverty in Namibia, and rural areas in these regions the two lowest estimates of annual consumption per capita (N$4,972 and N4,542 respectively) in 2009/10. They also had the second and third lowest annual consumption per capita in urban areas (after Kunene). Consequently people, particularly rural, resident in the ecosystem zone are thought to be some of the very poorest in Namibia.

The zone encompasses at least parts of a number of national parks: the Okavango river flows through the western side of the Bwabwata, while the Kwando borders the eastern side of the Bwabwata and the Mudumu and Nkasa Rupara (which lies completely within the zone). There are a also a number of conservancies that are at least partially in the zone: Joseph Mbambangandu borders the Okavango; Kwandu, Mayuni, Mashi and Balyerwa lie alongside the Kwando; and Salambala, Wuparo, Kasika, Impalila, Sikunga, Dzoti, Bamuna and Kabulabula lie along the Zambezi,

Linyanti, or Chobe rivers or within their floodplains. Some community forests are also found in the zone, although these are primarily within the borders of the conservancies.

5.1.1.3 Pressures and drivers of change

Table 9: Broad drivers of change and ecosystem-specific pressures in the NE Rivers ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Land degradation through clearing of land for crops; elephant damage to riverine woodland; overgrazing
Exploitation	Abstraction of water; harvesting of fish and plant products
Pollution	Contamination by pesticides, fertilizers, domestic waste and industrial effluent
Invasive species	Introduction of alien fish and invasive aquatic plants a possibility
Climate change	Changes in patterns of precipitation
Illegal use	Poaching and illegal exploitation of natural resources by neighbours of nominally protected areas

Table 9 relates the six broad categories of drivers of change to specific pressures within the NE Rivers ecosystem zone. The major pressures are occurring along the Okavango primarily as a result of increasing human populations and large-scale farming. Land degradation is occurring through the clearing of land for crops, elephant damage to riverine woodland and overgrazing, and can be expected to continue as a result of increasing populations on both the Namibian and Angolan sides.

Abstraction of water from the Okavango is also expected to increase as a result of continued growth in its use for irrigation (in both Angola and Namibia), domestic and industrial purposes and emerging urban centres (including a growing possibility of water being pumped to Windhoek and other central areas of Namibia, central-north Namibia, and Ondjiva in Angola); this would reduce rates of flow. The precedent effect of these bulk-water schemes would likely clear the way for even greater abstraction schemes since existing caution to sustain the Okavango Delta would dissipate. In addition to the resulting abstraction of water, the development of large-scale irrigation schemes are likely to lead to increased nutrient and pesticide levels in the Okavango.

Similar activities will also occur along the Zambezi, but the developments are likely to be smaller and the overall impact more moderate because the much greater size of the Zambezi should give it more resilience. Significant developments along the Kwando in both Angola and Namibia are unlikely for the foreseeable future, and consequently pressures are limited along this river.

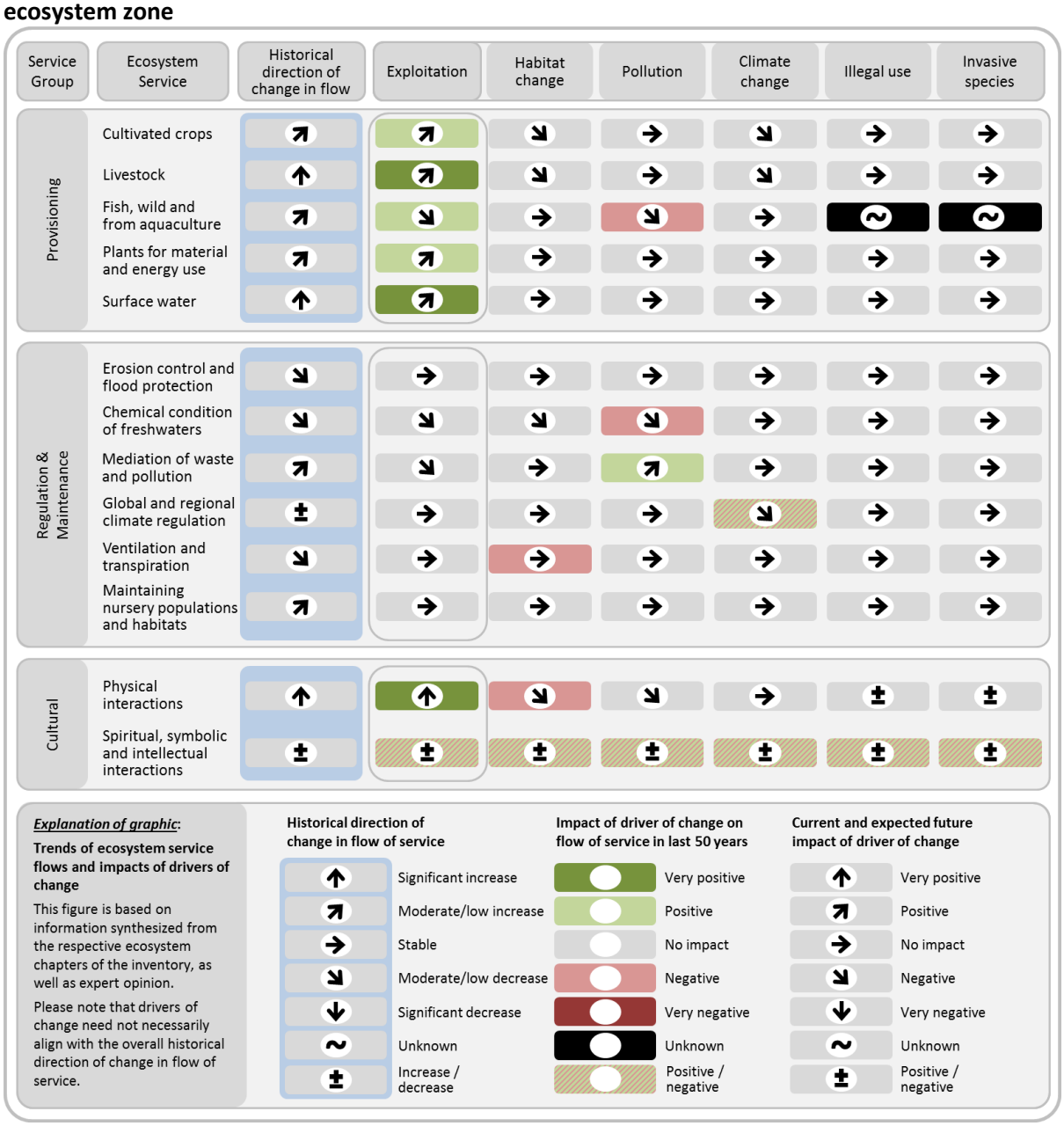
Modelled scenarios suggest that climate change will have an impact on the rivers, largely as a result of changes in precipitation in their catchments. While some scenarios suggest slight increases in rainfall, others project decreases; it is thus uncertain what changes will occur and when.

The introduction of alien fish species upstream in Angola is a possibility, but the potential impacts are not currently well understood. Poaching represents a threat in terms of the illegal use of resources. It has increased in recent years, but at its current level it is unlikely to significantly affect wildlife numbers.

5.1.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the NE Rivers ecosystem zone. Figure 5 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 5: Overview of flows of services and impacts from drivers of change in the NE Rivers ecosystem zone



5.1.2.1 Provisioning

Table 10 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the NE Rivers ecosystem zone (and which are comparable to those classes specified in Figure 5). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 10: Overview of provisioning services in the NE Rivers ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Cultivated crops	Pearl millet, sorghum, maize, vegetables	Local	Consumptive Use
Reared animals and their outputs	Meat and dairy products from livestock (cattle, goats, chickens)	Local	Consumptive Use
Reared animals and their outputs	Livestock as capital (cattle)	National	Option
Wild plants, algae and their outputs	Edible INP: bird plum, water lilies	Local	Consumptive Use
Wild animals and their outputs	Freshwater fish	Local	Consumptive Use
Surface water for drinking	Drinking water for urban and rural residents	Regional	Consumptive Use
Fibres and other materials from plants, algae and animals for direct use or processing	Reeds and other construction materials	Local	Consumptive Use
Surface water for non-drinking purposes	Water for domestic use, irrigation, livestock, industry and commerce	Regional	Consumptive Use
Plant-based resources	Wood fuel	Local	Consumptive Use

Description

A major provisioning service is the production of food through crops, meat and fish. The majority of rural residents grow dry-land crops, predominantly pearl millet, sorghum and maize; smaller numbers grow maize and vegetables in flood-recession fields. Most families have chickens, while about half have goats or cattle. Livestock is also increasingly being kept as a form of capital. Fish is harvested not only for own use but also for tradable purposes; when Lake Liambezi floods it can produce significant harvests which can be traded as far away as the Democratic Republic of the Congo (DRC).

Large-scale irrigation schemes have been established at intervals over several decades along the Okavango and Zambezi Rivers. Maize, wheat, millet and sunflowers are the main crops.

The provision of water for drinking and domestic use from the NE Rivers is crucial to the relatively dense populations that live in both urban and rural areas alongside them. Water is also used in the production of livestock; irrigation for growing crops (there are irrigation projects at a number of towns along the Okavango); and in industry or the provision of public and private services (such as hospitals and lodges).

Reeds that grow in the wetlands in the zone are used for building materials such as walls, mats, roofing etc. These and other local materials are also used to produce crafts for sale to tourists. There are also some edible indigenous natural products (INPs) in the ecosystem zone, such as water lilies and bird plum (*Berchemia discolor),* while wood is harvested for fuel.

Affected population

The affected population is primarily local because most of the services, such as the production of food from crops and livestock; water for livestock, irrigation, industry and domestic use; and the provision of building materials, are for own-use purposes by rural populations. Fish are generally also harvested for own-use reasons, but when harvests are significant they can be traded internationally. The extraction of drinking water also has relevance for rural populations that live further away from the rivers, and so is of regional importance; this could grow to national levels if it is decided to try and supply water from the NE Rivers to urban centres such as Windhoek. There is also a global impact, as abstraction from and interactions with the Okavango River and its tributaries in Namibia affect the downstream flow into Botswana. This is of particular concern for the Okavango Delta, which is a World Heritage site, an important tourism attraction and source of income, and a water source.

Change in flow over past 50 years

The flow of almost all provisioning services in this zone has increased strongly in the past 50 years, primarily reflecting increased demand due to rapid rural and urban population growth. The most significant increases in flow relate to the provision of water, particularly for urban residents, irrigation and livestock.

Pressures and expected impacts on flow of service

The increased flow in provisioning services relating to the production of food from crops and livestock over the past 50 years has occurred in spite of negative pressures on the capacity of the ecosystem zone to provide these services. Pressures from habitat change as a result of land degradation through overgrazing and clearing for crops are expected to continue particularly through increased numbers of livestock. The exploitation of crops and livestock for food is expected to continue growing, but at slower rates than in recent decades as a result of increasing movement of rural residents to urban environments, increasing dependence on off-farm incomes and the depletion of soil nutrients.

The pressures on the ability of the ecosystem zone to provide fish for food are also thought to be increasing. Pollution and contamination of the rivers may have had a slight negative impact on fish populations over the past 50 years, but this pressure is expected to grow as the use of pesticides, fertilisers and output of effluent from irrigation schemes and industry increases.

Very recently, indeed within the past 5 years, it is thought that over-harvesting of the fish resource has had a significant negative impact on fish populations, particularly in the Zambezi and the Okavango. These impacts will be exacerbated when production in Lake Liambezi drops. This is to be expected as the Lake has dried out periodically during long cycles of lower rainfall, most recently between 1985 and 2004.

The flow of surface water for drinking, livestock, irrigation, industry and domestic use is expected to continue to increase as populations grow, particularly in the Okavango where human activity is most significant. Furthermore, Namibia aspires to abstract more water for irrigation and water supplies to Windhoek, central-north Namibia and elsewhere.

5.1.2.2 Regulation and maintenance

Table 11 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the NE Rivers ecosystem zone.

Table 11: Overview of regulation and maintenance services in the NE Rivers ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Bio-remediation by micro-organisms, algae, plants, and animals	Detoxification of pollutants in rivers	International	Indirect Use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of pollutants in rivers	International	Indirect Use
Mass stabilisation and control of erosion rates	Vegetation cover protecting/stabilising riverine ecosystems	Regional	Indirect Use
Buffering and attenuation of mass flows	Transport and storage of sediments	International	Indirect Use
Flood protection	Flood protection by appropriate land coverage	Regional	Indirect Use
Ventilation and transpiration	Natural vegetation enabling air ventilation	Regional	Indirect Use
Maintaining nursery populations and habitats	Conditions in flood plains and Lake Liambezi for production	Regional	Indirect Use
Chemical condition of freshwaters	Maintenance of condition of freshwater	International	Indirect Use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect Use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect Use

Description

The mediation of waste, toxins and other nuisances occurs at both the level of the biota, in terms of detoxifying and filtering pollutants, as well as the ecosystem zone which works as a whole to dilute pollutants. The ecosystem zone mediates mass flows, through the transport and storage of sediments and vegetation cover protecting or stabilising riverine vegetation; liquid flows, as riverine woodland offers some flood protection; and gaseous flows, as natural vegetation enables air ventilation. The maintenance of physical, chemical and biological conditions is generated through a broad range of services, from the maintenance of the chemical condition of the freshwater, global climate regulation as a result of carbon sequestration, micro and regional climate regulation and the maintenance of conditions in flood plains that enable significant production to occur in these areas.

Affected population

The rivers in the ecosystem zone directly border Angola, Botswana and Zambia. Further downstream, they flow through Zimbabwe and Mozambique; as a result, many of the regulation and maintenance services, particularly those relating to the mediation of waste and toxins, affect international populations. Flood protection and the maintenance of the productive conditions are primarily relevant at a regional level, while carbon sequestration is important globally.

Change in flow over past 50 years

Flows of services relating to the mediation of waste and toxins are estimated to have increased slightly as a result of increased pollution inducing both the biota and ecosystem zone to work harder; this is having a similar effect on the transport and storage of sediments. On the other hand, the flow of carbon sequestration, flood protection, the protection/stabilisation of riverine ecosystem zones and air ventilation services have decreased over the past 50 years as a result of declines in riverine woodland. The maintenance of the condition of the water has declined as a result of pollution.

Pressures and expected impacts on flow of service

Increased pollution is likely to lead to greater flows of services mediating waste and toxins, but the abstraction of water could reduce the capacity of the ecosystem zone to deliver these services. Pressure from habitat change is expected to continue to have slight negative impacts on flood protection and carbon sequestration. However, pollution could drive eutrophication and consequently increased plant biomass, slightly increasing carbon sequestration.

The overall impact on the transport and storage of sediments is not clear; the rivers are expected to continue carrying sediments, but reductions in water flow could limit their capacity. The maintenance of the condition of river water is likely to be increasingly affected by increased pollution, siltation resulting from land degradation and reduced flows.

Increased pollution in the rivers could have negative impacts on the maintenance of conditions for production in flood plains and Lake Liambezi. Micro and regional climate regulation services could be altered by climate change.

5.1.2.3 Cultural

Table 12 details the specific services that relate to the broad cultural ecosystem service classes relevant to the NE Rivers ecosystem zone.

Table 12: Overview of cultural services in the NE Rivers ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Recreational tourism to include wildlife viewing, bird watching, landscape appreciation	International	Non-consumptive use
Physical use of land-/seascapes in different environmental settings	Recreational fishing	International	Consumptive use
Scientific	Research on variety of topics	International	Non-consumptive use
Heritage, cultural	Some San tribes; Zambezi people and languages	International	Non-consumptive use
Entertainment	Ex-situ viewing of wildlife, landscapes	International	Existence
Sacred and/or religious	Island burial grounds for Hambukushu chiefs	Regional	Bequest
Existence	Relating to wildlife	International	Non-consumptive use
Bequest	Relating to wildlife	International	Non-consumptive use

Description

Cultural services relate heavily to the unique landscapes, biodiversity and large wildlife populations that the ecosystem zone supports. Recreational tourism, such as wildlife viewing and boating, as well as consumptive tourism, such as trophy hunting, and leisure fishing, both occur in the ecosystem zone. Features of the ecosystem zone have also encouraged scientific research on topics such as human-wildlife conflict, wildlife migration corridors and the 'wet and dry' nature of the productivity of floodplains and areas such as Lake Liambezi.

There are significant heritage and cultural services associated with the ecosystem zone; it is home to San people, as well as Zambezians (formerly Caprivians), and represents certain ways of life and livelihoods. The riverine systems also provide for island burial grounds of Hambukushu Chiefs. The large wildlife populations give rise to existence and bequest services that people hold for these species, as well as the ways of life and livelihoods of the San and Zambezians in the zone.

Affected population

The cultural services generated by this zone are primarily of international value because they are heavily related to tourism, plant and animal species and landscapes of global interest. Tourists are a mix of high (e.g. staying in exclusive lodges) and relatively low (e.g. self-drive, staying in community campsites) expenditure individuals or groups.

Change in flow over past 50 years

Recreational tourism, landscape appreciation and scientific research services are all thought to have increased significantly in the ecosystem zone following independence. The use of the ecosystem zone for island burial grounds has not demonstrated any meaningful change. The change in flow of heritage, cultural, bequest and existence services is largely unknown because these are conceptual services and currently not very well understood.

Pressures and expected impacts on flow of service

The identified pressures are not thought to have had a significant impact on cultural services over the past 50 years, although land degradation has perhaps resulted in low-level impacts on landscape appreciation. However, pressures on some cultural services, particularly with regard to recreational tourism and landscape appreciation, are expected to increase.

Recreational tourism could be negatively affected by a range of pressures: land degradation reducing habitats for wildlife and therefore affecting wildlife viewing; water abstraction reducing flow rates and affecting leisure fishing and potentially recreational boating; riverine pollution impacting fish populations and consequently leisure fishing and the enjoyment from boating; and illegal use (poaching) potentially reducing wildlife numbers and damaging the image of the region, and consequently impacting wildlife viewing (although at current levels it is not a significant threat).

However, tourist numbers are expected to continue increasing. Tourist arrivals in Namibia have increased from almost 780,000 in 2005[34] to more than 1.3m in 2014[35], and the World Travel and Tourism Council projects this to increase to more than 2m by 2024[36]. However despite the abundance of wildlife and the unique landscapes in the ecosystem zone, and the main reasons stated for visiting for Namibia as a whole being 'wildlife' and 'scenery', it is estimated that only around 5% of international tourists coming to Namibia visit the Zambezi region[37]. This suggests that there is considerable scope for increased tourism in the ecosystem.

The NE Rivers landscapes are also likely to be increasingly negatively affected by land degradation, water abstraction and riverine pollution. The effects of drivers of change on the sacred and scientific services are thought to be limited, while the heritage, cultural, existence and bequest services are currently not particularly well understood. For example, habitat change could restrict some ways of life in the future, while bequest and existence services could be affected negatively by poaching.

5.1.2.4 Interactions between ecosystem zones and ecosystem services

The freshwater from the NE Rivers is crucial in supporting human populations in the Zambezi and Kavango regions that live inland from their floodplains (i.e. in the northern parts of the Northern Kalahari Woodlands). This is not only through the direct provision of the water itself, but also through the wildlife and biodiversity it supports which are also utilised for recreational tourism and hunting in this zone.

[34] MET, 2012
[35] MET, 2015a
[36] WTTC, 2014
[37] MET, 2013. We take this as a proxy for the NE Rivers ecosystem.

The Okavango and the Zambezi have significant downstream value in other countries. The Okavango feeds the Okavango Delta in Botswana which is both a World Heritage Site and a Ramsar Site, while the Zambezi continues to the Victoria Falls, another World Heritage site, source of hydro-power, and the largest sheet of falling water in the world. Impacts on flow and pollution could impact negatively on these areas.

Several services within the ecosystem zone are closely interlinked. If the abstraction of surface water continues to increase, this could impact negatively on regulation and maintenance services such as the mediation of waste and pollutants and the transport and storage of sediments.

5.1.3 Criteria for prioritisation of ecosystem services

5.1.3.1 Current and future expected impacts on the flow of the service

The provisioning services facing the greatest threats are cultivated crops, livestock (both as a result of habitat change and climate change) and fish (through overexploitation). The maintenance of the condition of freshwaters is under pressure from increased pollution and possible reductions in flow.

5.1.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

Increased abstraction of surface water could reduce flows and affect a number of regulation and maintenance services such as the mediation of waste and pollutants, maintenance of condition and transport and storage of sediments. If realised, these services would be most affected along the Okavango.

Expansion of urban areas and increasing industrialisation

Increasing industrialisation could result in more pollution in the rivers and increase pressure on the chemical condition of freshwaters, as well as threatening fish populations, particularly if it affects Lake Liambezi.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the ecosystem zone to be used for agriculture.

Rapid expansion of mining and prospecting

There are no threats from the rapid expansion of mining and prospecting in this ecosystem zone.

Unsustainable land management practices

Although total livestock numbers are probably below carrying capacity in the zone, there may still be overgrazing in concentrated areas as a result of the lack of movement of livestock. Harvesting of riverine vegetation could reduce flood protection.

Uncontrolled bush fires

There are no threats from uncontrolled bush fires in this ecosystem zone.

Alien invasive species

There are few, if any, threats from the alien invasive species in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

If poaching continues it could represent a threat to recreational tourism in the zone (both consumptive and non-consumptive).

Human-wildlife conflict

Human-wildlife conflict is an ongoing threat to livestock farming and crop production and could affect recreational tourism if it negatively impacts on wildlife populations.

5.1.3.3 Economic importance (current and potential)

The most significant service in economic terms is probably recreational tourism; it is crucial to the functioning of the conservancies in the zone. As discussed in Section 0 it is also thought to have considerable growth potential.

5.1.3.4 Affected population (size and socio-economic characteristics)

The provision of water is important to populations through this and neighbouring ecosystem zones, both urban and rural. Given the low income and high poverty incidence of rural populations in the zone, the provisioning services that are used to produce food, particularly for own use, are also extremely important. Although not well understood, the cultural services could also be relevant to some of the very poorest groups resident within the zone, for example the San.

5.1.3.5 Availability of data

The services with the greatest availability of data are likely to be marketed provisioning services (such as livestock, crops and fish), as these transactions are registered and consequently the estimation of their flows is relatively simple. It should also be possible to obtain data for the number of tourists visiting the area and staying in different types of accommodation. NGOs, research, and Government institutions operating in the area are likely to have some data regarding the condition/flows/levels of the rivers and lakes in the ecosystem zone, and some estimates of the incidence of invasive species, poaching and human-wildlife conflict.

5.1.4 References

Bethune, S. 1991. Kavango River wetlands. Madoqua 17: 77-112.

Cole, D. et al. 2014. Indigenous Plant Products in Namibia. Venture Publications. Windhoek.

Jones, B.T.B. and SIAPAC. 2001. Socio-ecological survey report for the Okavango River Basin (Botswana and Namibia). Every River has its People project, Windhoek

Keyler, S. 1995. Economics of the pearl millet subsector in Northern Namibia. A summary of baseline data. International Crops Research Institute for the Semi-Arid Tropics. Working Paper 95/03.

Mendelsohn, J.M. 2006. Farming systems in Namibia. RAISON, Windhoek.

Mendelsohn JM. 2008. Customary and legislative aspects of land registration and management on communal land in Namibia. Report for Ministry of Lands and Resettlement.

Mendelsohn JM. and el Obeid S. 2003. Sand and Water: a profile of the Kavango region of Namibia. Struik, Cape Town.

Mendelsohn JM and Roberts, CS. 1997. An Environmental Profile and Atlas of Caprivi. Directorate of Environmental Affairs, Windhoek, Namibia.

Schneider, MB. 1987. Notes on terrace soils of the Kavango River, Northern SWA/Namibia. Journal of the SWA Scientific Society 40/41: 199–213. Windhoek.

Strohbach, B.J. Vegetation of the Okavango River valley in Kavango West, Namibia. In: Oldeland, J., Erb, C., Finckh, M. and Jürgens, N. (eds). 2013. Environmental Assessments in the Okavango Region. Biodiversity and Ecology, 5: 321–339

Tweddle D. 2010. Overview of the Zambezi River System: Its history, fish fauna, fisheries, and conservation. Aquatic Ecosystem Health and Management, 13: 224 — 240.

Tweddle D, Cowx IG, Peel RA and OLF Weyl. 2015. Challenges in fisheries management in the Zambezi, one of the great rivers of Africa. Fisheries Management and Ecology 22: 99–111

Van der Waal, B.C.W. 1990. A survey of the fisheries in the Kavango, Namibia. Madoqua 17: 113–122

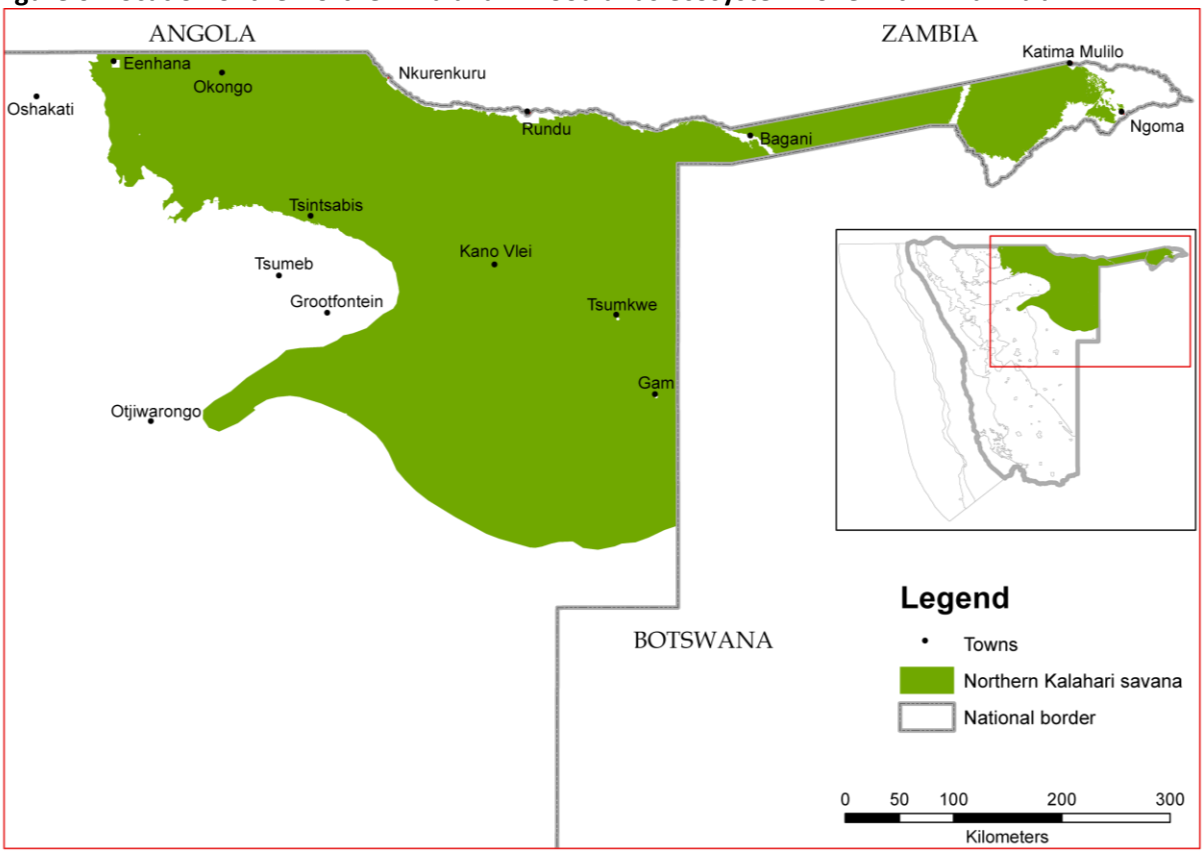
5.2 Northern Kalahari Woodlands

5.2.1 Description and assessment of ecosystem zone

5.2.1.1 Main attributes and ecological processes

The Northern Kalahari Woodlands cover approximately 155,000 square kilometres of Namibia (Figure 6). Along with the Dry Kalahari Woodlands and the Namib Sand Sea, it is one of three major expanses of aeolian sand in Namibia. The Northern Kalahari Woodlands lie immediately to the north of the Dry Kalahari Woodlands, and together they form a small section of the Kalahari Basin that covers a large part of inland Africa south of the Equator.

Figure 6: Location of the Northern Kalahari Woodlands ecosystem zone within Namibia



Rainfall is the primary factor that distinguishes the Northern Kalahari from the Dry Kalahari, approximately along the 400mm isohyet. North of this isohyet in the northern Kalahari, rainfall increases to about 550mm in the north-west (in Ohangwena) and 650mm in the north-east (Zambezi).

Woodlands in the Northern Kalahari are generally tall (10-15 metres) and deciduous. They are usually dominated in any one area by several of the following species: *Burkea africana (*burkea*), Baikiaea plurijuga (*Zambezi teak*), Pterocarpus angolensis (kiaat* or Angola teak*), Guibourtia coleosperma (*false mopane or *mukwe), Combretum collinum* (variable Combretum)*, Acacia erioloba (*camelthorn*), Terminalia sericea (*silver terminalia*), Schinziophyton rautanenii* (*mangetti*) and *Erythrophleum africanum* (African blackwood).

These species all grow on deep sands, which are typically low in nutrients (particularly phosphorus) as a result of the inert quartz parent material and nutrient leaching; frequent fires probably also contribute to the depletion of nutrients. Grass and shrub cover in the woodlands is typically sparse and has limited forage value, and, along with the absence of any surface water in the sands, contributes to generally low carrying capacities and biomass of wildlife and livestock.

In and about the sands are many small pans, inter-dune valleys and several fossil river courses (*omurambas*), the biggest of which are the Mpungu, Omatako, Khaudom, Nhoma, Eiseb, Epukiro and Otjozondjou. The pans, inter-dune valleys and river courses typically have fine grained alluvial silts or clay and are comparatively fertile. These are the only places where water has historically been available to people, livestock and wildlife. The water is either found on the surface after rain or in shallow wells.

All the alluvial features and their sediments were formed during much wetter cycles over millennia. Dunes and inter-dune valleys were conversely formed during dry cycles when rainfall approached 150mm per year, which is the current level of rainfall in the active dune fields in south-eastern Namibia.

The woodlands are fairly open in most areas, forming a savanna landscape; the exceptions are in eastern Ohangwena, north-western Kavango and the western areas of Bwabwata National Park, where dense, forested patches of Zambezi teak can be found. The land is generally extremely flat throughout the ecosystem zone, bar the slight undulations around old pans and dunes and the isolated Waterberg mountain which rises some 400m above the surrounding terrain.

Wildlife found in the zone can be quite diverse, particularly in the Zambezi region where it is bordered by the NE Rivers. Here large mammals such as elephant and giraffe, as well as range of predators including the endangered and rare (particularly within Namibia) African wild dog. The zone is also particularly important as the habitat of a variety of poorly known fossorial reptiles, as well as invertebrate groups that are uncommon or absent elsewhere in Namibia.

The Waterberg Plateau Park is also home to a number of large mammals, including black and white rhino, Cape buffalo and giraffe, while tsessebe, sable and roan antelope have been relocated to the Park for breeding purposes. More than 200 species of bird have been recorded in the Park, including Namibia's only breeding colony of Cape vultures; the latter are the rarest birds in Namibia. Several semi-endemic bird species occur on the Waterberg as well as other range-restricted reptiles and invertebrates.

5.2.1.2 Human activity and population

Eenhana is the only substantial town in the ecosystem zone, and it is also the capital of Ohangwena. In 2011 its population was estimated at 5,500, representing almost twice the population in 2001 (2,800). All other urban areas are small, each with less than 3,000 residents: Okongo, Mururani, Mpungu Vlei, Gam, Tsumkwe, Okamatapati and Tsintsabis. Most residents depend on larger towns outside the ecosystem zone for services and supplies, such as Rundu, Ondangwa, Grootfontein and Otjiwarongo.

The rural population in the ecosystem zone was estimated at 288,000 in 2011, an increase of approximately 12% since 2001 (257,000). This corresponds to a rural population density of

approximately 1.85 people per km^2, which is actually the third largest of all the rural ecosystem zones in Namibia[38]. The majority of the rural population live in the north-west of the ecosystem zone that falls within Ohangwena and Oshikoto Other concentrations of people live close to the road between Mururani and Rundu, along the Ndonga *omuramba* between Rundu and Ncaute, east of the Kwando River and along major roads in Zambezi.

Most of the area is formally under communal tenure, but several hundred private, fenced farms, each covering thousands of hectares, have been established. As much as half of all the communal land is now effectively privately owned. Most large farms in Kavango East and West have leasehold rights, many up to 99 years, provided by Communal Land Boards. Elsewhere in the communal areas, residents have usage rights over land rights. These are called customary land rights. They are not tradable and thus have little investment value for local residents. Most rural income is derived from social grants, remittances, wages, businesses and other off-farm sources.

It is not easy to estimate the socio-economic characteristics of the population in the Northern Kalahari Woodlands because it encompasses parts of Zambezi, Kavango, Ohangwena, Oshikoto and Otjozondjupa, and much of the latter falls outside of the zone. However it is likely that the rural populations are generally poor as these regions have the five highest incidences of poverty across the whole of Namibia. With the exception of Otjozondjupa, all have lower than average rural consumption per capita.

Khaudom, Mangetti and the Waterberg Plateau national parks are completely within the Northern Kalahari Woodlands, while Bwabwata and Mudumu lie primarily within the ecosystem zone but are shared with the NE Rivers ecosystem zone. The zone encompasses at least parts of 23 conservancies and 21 community forests, as well as two government-managed forest areas (the Hamoye and Caprivi State Forests), although neither are gazetted as protected or state land.

5.2.1.3 Pressures and drivers of change

Table 13: Broad drivers of change and ecosystem-specific pressures in the Northern Kalahari Woodlands ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Woodland loss and structure change due to frequent, hot fires; overgrazing; bush encroachment; privatisation and fencing of large farms
Exploitation	Abstraction of water; harvesting of wood and crops; increases in livestock numbers
Pollution	No relevant pressures in this zone
Illegal use/Invasive species	No relevant pressures in this zone
Climate change	Potential to increase rate of bush encroachment
Illegal use	Poaching

Table 13 relates the six broad categories of drivers of change to specific pressures within the Northern Kalahari Woodlands ecosystem zone. Habitat change is occurring primarily as a result of fires in the woodland and overgrazing. Indeed, the fires that sweep across the Northern Kalahari

[38] Although the second largest is the NE Rivers with 19 people per km^2 which is significantly higher.

Woodlands each year are particularly prominent and characteristic of the area, and represent the most significant driver of change in the ecosystem zone, resulting in woodland loss and changes in its structure.

Land degradation and bush encroachment is being driven by overgrazing by increased numbers off livestock (particularly cattle), the owners of which almost all live elsewhere. The concentration of cattle in private, fenced farms is resulting in habitat change and limits movement, foraging, and watering options for wildlife.

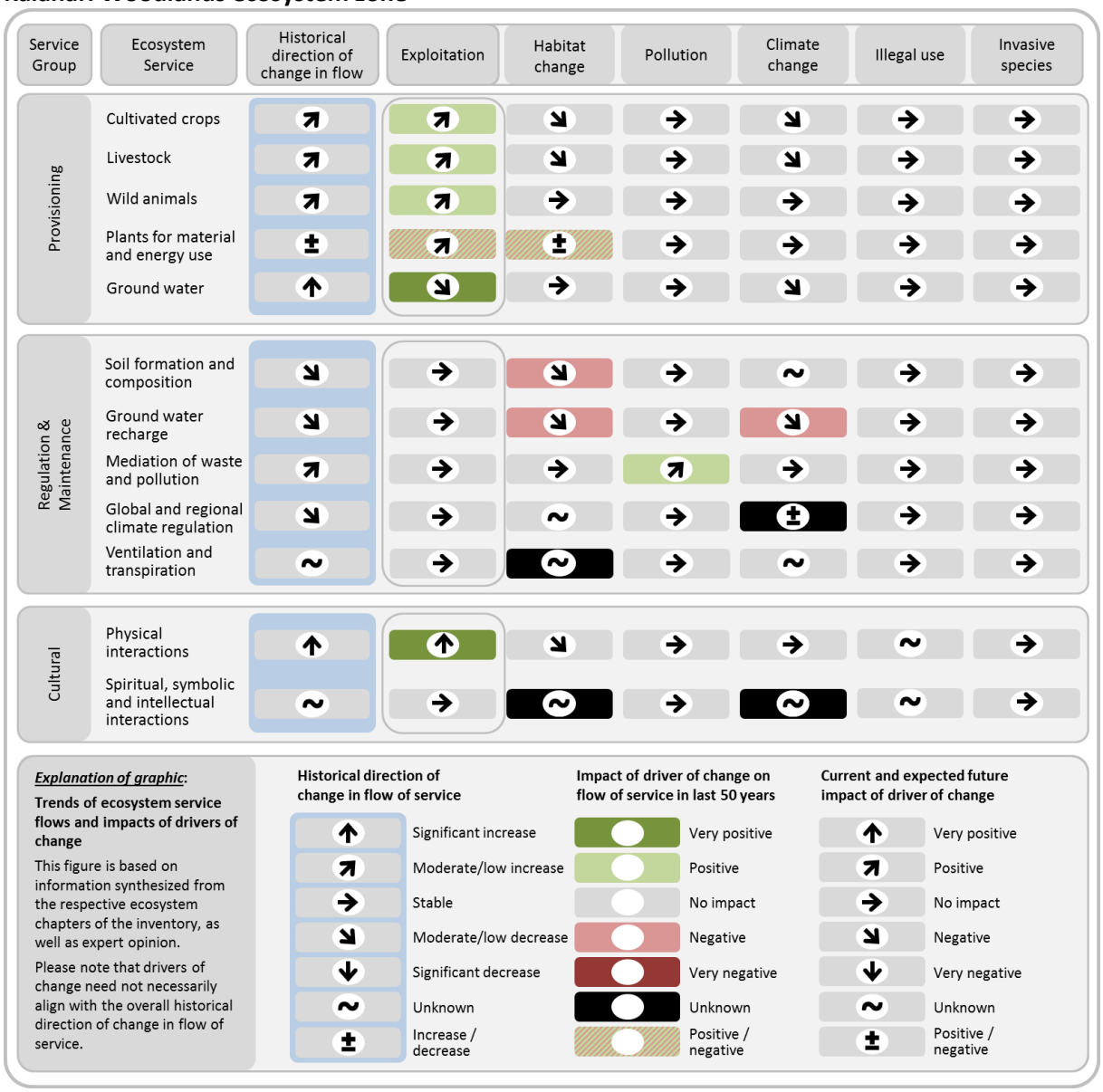
Exploitation is in the form of abstraction of groundwater, harvesting of wood, and production of crops and livestock. The abstraction of groundwater is being driven by increased rural populations and cattle numbers. Both of these are likely to grow less quickly in the future; the former as there is increased rural-urban migration and the latter as carrying capacities are reached or exceeded. The exploitation of livestock is consequently not expected to grow as quickly going forwards.

Climate change may put upward pressure on rates of bush encroachment but there are no relevant pressures relating to pollution or alien invasive species in this zone. However, poaching, particularly in the Zambezi region, and illicit timber harvesting represent an increasing pressure related to illegal use.

5.2.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Northern Kalahari Woodlands ecosystem zone. Figure 7 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 7: Overview of flows of services and impacts from drivers of change in the Northern Kalahari Woodlands ecosystem zone



5.2.2.1 Provisioning

Table 14 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Northern Kalahari Woodlands (and which are comparable to those classes specified in Figure 7). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 14: Overview of provisioning services in the Northern Kalahari Woodlands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Cultivated crops	Pearl millet, sorghum, maize, vegetables	National; local	Consumptive Use
Reared animals and their outputs	Meat and dairy products from livestock (cattle, goats)	National	Consumptive Use
Reared animals and their outputs	Livestock (cattle) as capital	National	Option
Wild animals and their outputs	Meat from wildlife	Local	Consumptive Use
Groundwater for drinking	Drinking water pumped from aquifers	Local	Consumptive Use
Fibres and other materials from plants, algae and animals for direct use or processing	Thatching grass, timber, other wood for construction, hides from livestock	Local	Consumptive Use
Fibres and other materials from plants, algae and animals for direct use or processing	INPs such as Devils Claw for medicinal products; skins and trophies from wildlife	International	Consumptive Use
Groundwater for non-drinking purposes	Water for domestic use, crops, livestock and wildlife pumped from aquifers	Local	Consumptive Use
Plant-based resources	Wood fuel	Regional; local	Consumptive Use
Animal-based energy	Donkeys for transporting people and goods	Local	Consumptive Use

Description

Agricultural activities represent the dominant land use in the zone. Small-scale cereal production for own use happens throughout the zone, but maize and millet are farmed commercially in small areas in the inter-dune valleys in southern Kavango West and on freehold farms in northern Otjozondjupa.

Meat and dairy is produced from livestock, in particular cattle and goats. Cattle are also kept as a form of capital. Farms in Kavango East, Kavango West, Oshikoto and Ohangwena are largely used for cattle keeping, while farms in Otjozondjupa and Omaheke are primarily for cattle farming.

Wildlife is also harvested for meat, and hunting and gathering remains part of the livelihoods of some San people throughout much of the zone, particularly in eastern Otjozondjupa. Drinking water is pumped from aquifers; these sources are also used to provide water for domestic use and the production of crops, livestock and wildlife.

Plant products are used to provide services in a number of ways: trees are harvested commercially for timber; thatching grass and other wood products are used for construction (mainly of housing); wood is used for fuel to cook and heat materials; and indigenous natural products such as Devil's Claw are harvested to produce medicinal products. Livestock and wildlife also provide hides, skins, horns and trophies, while donkeys in particular are used to transport people and goods between rural areas.

Affected population

The relevant population for the provisioning services relating to water, materials and energy is almost entirely local, as they are generally used at the point of extraction or harvesting. Exceptions are indigenous natural products used for medicine, as these are largely exported internationally, and skins/trophies of wildlife which are also consumed at international and national levels.

Meat and dairy from cattle is consumed at the national level, while nutrition derived from goats and wildlife is primarily relevant to local populations. Livestock held as capital is relevant to national populations because a significant proportion of the owners live outside of these rural areas, often in other ecosystem zones. Crops grown in the zone are primarily for own-use.

Change in flow over past 50 years

The flow of almost all provisioning services in this zone has increased in recent decades; this is primarily as a result of increased human exploitation. The services demonstrating the most significant increases are cattle keeping (as capital) and water for crops, livestock and wildlife (as a result of increased livestock and wildlife numbers, and increased numbers of households growing crops).

The only service provisioning service to have declined over this time period is timber. Angola teak or *mukwe* occur widely in the zone, but the larger trees were cut for timber in the 1960s and 1970s; since then, the timber industry has been largely inactive. These timber species grow extremely slowly, taking decades to reach sizes where they have commercial value as timber.

Pressures and expected impacts on flow of service

The exploitation of provisioning services relating to food are expected to continue growing, but at slower rates as rural populations grow more slowly or start to decline in some areas. Increases in cattle kept as capital are expected as these are driven largely by urban populations living outside of the zone.

However there are also additional pressures on these services. Land degradation as a result of overgrazing and bush encroachment is reducing carrying capacity, and consequently the ability of the ecosystem zone to support the production of livestock and potentially wildlife for the production of meat; to a slightly lesser extent this also impacts on the keeping of cattle as capital. Climate change may also negatively impact on availability of suitable land for these purposes if warmer conditions and greater carbon dioxide levels increase the rate of bush encroachment. The production of crops may be limited in the future by nutrient availability when all arable areas have been exploited.

The exploitation of groundwater is also expected to increase but at a slower rate than previously; this is again due to the reduced rate of growth of rural populations. Increased bush encroachment may limit growth in this service. The discovery of a productive aquifer in the Eiseb area could result in increased exploitation.

There is not expected to be any change in the provision of timber going forwards until the relevant species reach commercial size. The exploitation of thatching grass and wood for construction is not

expected to grow significantly, again as a result of reduced growth in rural populations; there may be some reduction in the potential of the ecosystem zone to provide this service as a result of losses due to fire. Growth in the exploitation of INPs and wildlife for skins and trophies is expected to continue, although at a relatively slow rate.

The use of wood fuel is not expected to increase at the local level, but increased bush density may encourage offtake for the purpose of exporting firewood to other zones, particularly to supply growing numbers of urban residents who cannot afford other fuel[39]. Donkeys as a source of transportation are expected to decline as incomes and access to vehicle transportation increase.

5.2.2.2 Regulation and maintenance

Table 15 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Northern Kalahari Woodlands.

Table 15: Overview of regulation and maintenance services in the Northern Kalahari Woodlands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Filtration/sequestration/storage/ accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect Use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect Use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect Use
Ventilation and transpiration	Vegetation enabling air ventilation	Regional	Indirect Use
Maintaining nursery populations and habitats	Waterberg as breeding habitat for species requiring special conservation measures	International	Indirect use
Weathering processes	Maintenance of fertility of soils, nutrient storage and soil structure	Local	Indirect Use
Decomposition and fixing processes	Decomposition/mineralisation of dead organic material, nitrification	Local	Indirect Use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect Use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect Use

[39] Significant piles of dry wood (up to 100m in length and 5m high) seen alongside district roads east of Okakarara and repeated every 5 – 10 km. Pers. Comm. Gobabeb Review team.

Description

The mediation of waste, toxins and other nuisances occurs largely at the ecosystem level by the absorption of pollutants and the dilution of gases into the atmosphere. The mediation of flows relates to both liquids, with regard to groundwater recharge, and gases, through vegetation enabling air ventilation.

There are three groups of services relating to the maintenance of physical, chemical and biological conditions: soil formation and composition, (through both the decomposition/mineralisation of dead organic material and nitrification, as well as the maintenance of the fertility of soils, nutrient storage and their soil structure), atmospheric composition and climate regulation (through carbon sequestration and the maintenance of regional precipitation/temperature patterns), and the maintenance of nursery populations and habitats. Waterberg is particularly relevant with regard to the latter service; it represents a critical breeding habitat for endangered species, including white and black rhino. It is also used as a nursery habitat for roan and sable antelope and tsessebe.

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of liquid and gaseous flows. The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level. Waterberg as a critical breeding habitat is relevant internationally to the extent it supports internationally recognised and endangered species. Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

The absorption and dilution of pollutants in the ecosystem zone have likely risen as a result of slightly increased pollution from higher populations and greater human activity, although this is probably of limited importance. Increased coverage of bush in the zone is estimated to have reduced the rate of groundwater recharge. Overgrazing, clearing of woodland and fires in the ecosystem zone have resulted in a reduction in the flow of the soil formation and composition processes. Carbon sequestration is also estimated to have been reduced as a result of the clearing of woodland, but may have been offset somewhat by greater bush density. The importance of Waterberg as a critical habitat for endangered species has increased significantly in recent decades as a result of rising use for this purpose. The overall change in air ventilation and micro and regional climate regulation is unknown.

Pressures and expected impacts on flow of service

The absorption and dilution of pollutants is expected to continue increasing as human activity in the ecosystem zone keeps expanding, although it is still likely to be a relatively insignificant service. If encroacher bush continues to thicken, the rate of groundwater recharge is likely to be further reduced.

The negative effects from habitat change on soil formation and composition are also likely to continue, as a result of continued overgrazing and bush encroachment. Climate change may also impact negatively on these processes.

There is uncertainty around the effects on carbon sequestration, as increased woody biomass as a result of bush encroachment could increase carbon sequestration, but habitat change that reduces available woodland could reduce it. Climate change could also reduce regional precipitation, resulting in more arid conditions, but it is unclear how significantly rainfall will decrease and over what time period it will occur.

It is also not clear how the service relating to Waterberg as a critical habitat for endangered species will change. Given its size, its capacity to provide continued growth in this service is limited, but increased pressure from poaching could increase its importance in this regard.

5.2.2.3 Cultural

Table 16 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Northern Kalahari Woodlands.

Table 16: Overview of cultural services in the Northern Kalahari Woodlands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Wildlife viewing; landscape appreciation; hiking	International	Non-consumptive use
Physical use of land-/seascapes in different environmental settings	Trophy hunting; shoot and sell	International	Consumptive use
Scientific	Waterberg; research on variety of topics	International	Consumptive use, non-consumptive use
Educational	Waterberg	National	Non-consumptive use; existence; bequest
Heritage, cultural	Waterberg for Hereros; San people; Hereroland and Bushmanland homelands	National	Non-consumptive use; existence; bequest
Entertainment	Ex-situ viewing of wildlife	International	Non-consumptive use
Aesthetic	Representation of Waterberg	International	Non-consumptive use
Symbolic	Relating to livelihoods, way of life, keeping cattle	National	Consumptive use; non-consumptive use; option
Sacred and/or religious	San	National	Non-consumptive use; existence; bequest
Existence	Relating to wildlife; Hereroland and Bushmanland homelands	International	Existence
Bequest	Relating to wildlife; Hereroland and Bushmanland homelands	International	Bequest

Description

Recreational tourism in the form of wildlife viewing, landscape appreciation and recreational hunting occurs primarily in the conservancies and national parks in the zone; Waterberg is also a key site for hiking. There are significant services provided by scientific research and education, with Waterberg again an important location for these services. The zone also gives rise to ex-situ wildlife viewing and representations of Waterberg as a distinct feature are an important aesthetic service.

Heritage, symbolic and cultural services occurring in the zone include those relating to the San people who live in the zone; the former designations of part of the area covered by the Northern Kalahari Woodlands as Hereroland and Bushmanland pre-independence; and broad services relating to livelihoods and the way of life, such as the keeping of cattle. Waterberg is the site of the Battle of

Waterberg, and has significant importance particularly to the Herero people and more broadly in Namibian history. It is not known whether the San have specific rituals or sacred practices relating particularly to areas in the ecosystem zone. Existence and bequest services may be held relating to wildlife in the zone, as well as to livelihoods and ways of life.

Affected population

Tourists to the zone are primarily international visitors; the ex-situ viewing of wildlife, scientific services and the existence and bequest services relating to wildlife are also relevant to international populations. The other services are all relevant to individuals living across Namibia.

Change in flow over past 50 years

Recreational tourism has increased significantly in recent decades; tourism facilities have been developed in a number of the conservancies as well as in the national parks. Scientific services are also thought to have increased. The flow of services relating to other cultural services is not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone, particularly as facilities to support expansion are currently being developed in Khaudum. Habitat change and poaching could represent threats in the longer term to recreational tourism, but are unlikely to affect the service at current rates. The effects of pressures on other cultural services are generally poorly understood, but it is possible, for example, that habitat change could impact on the cultural values the San hold if their traditional practices are confined to smaller areas.

5.2.2.4 Interactions between ecosystem zones and ecosystem services

A key interaction within the ecosystem zone results from the effect of overgrazing, the fencing off of private farms and the absence of fires in these areas which is leading to land degradation (declines in the soil formation and composition services) and bush encroachment. Bush encroachment may be reducing the rate of groundwater recharge in the zone. The farming and keeping of livestock is likely linked with cultural services relating to ways of life for farmers, but conversely reduces the area over which the San are able to practice their own way of life and livelihoods. As discussed in Section 5.1.2.4, there is also a critical overall interaction with the NE Rivers ecosystem zone.

5.2.3 Criteria for prioritisation of ecosystem services

5.2.3.1 Current and future expected impacts on the flow of the service

The provisioning services facing the greatest threats to their flow are cultivated crops and livestock (both as a result of habitat change through bush encroachment and climate change)

5.2.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

There are limited threats from unsustainable water use in this ecosystem zone.

Expansion of urban areas and increasing industrialisation

There are limited threats from industrialisation in this ecosystem zone.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the ecosystem zone to be used for agriculture, as well as the rate of groundwater recharge.

Rapid expansion of mining and prospecting

There are limited threats from the rapid expansion of mining and prospecting in this ecosystem zone.

Unsustainable land management practices

Overgrazing could be having significant impacts in the zone, resulting in land degradation. This in turn could be reducing the rate of groundwater recharge, as well as affecting some cultural services.

Uncontrolled bush fires

Bush fires are characteristic of the area, and represent a threat to pastures and woodland in the zone, consequently impacting on services such as livestock production, timber harvesting, and carbon sequestration. They are most prevalent where there is limited grazing of livestock, however, so its impact on livestock farming is likely to be limited.

Alien invasive species

There are no significant threats from alien invasive species in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

If poaching continues it could represent a threat to recreational tourism in the zone.

Human-wildlife conflict

Human-wildlife conflict could impact on recreational tourism if it negatively impacts on wildlife populations, and is an ongoing threat to livestock farming and crop production.

5.2.3.3 Economic importance (current and potential)

The potential for beef production in the zone is significant. Recreational tourism is likely to grow in the future as tourism facilities are developed further (e.g. in Khaudum).

5.2.3.4 Affected population (size and socio-economic characteristics)

The provisioning services related to the production of food, particularly for own use, are probably of the greatest immediate importance to the largest populations in the zone, especially because it encompasses parts of the five poorest regions in Namibia. Although not well understood, the cultural services are likely to be relevant to some of the very poorest groups resident within the zone, for example the San.

5.2.3.5 Availability of data

The services with the greatest availability of data are likely to be marketed provisioning services (such as livestock and crops), as these transactions are registered and consequently the estimation of their flows is relatively simple. It should also be possible to obtain data for the number of tourists visiting the area and staying in different forms of accommodation. Conservancies and national parks conduct game counts on an annual basis to estimate wildlife populations. Scientific research in the ecosystem zone may be able to provide some data on ecosystem processes, particularly with respect to the Waterberg area. The extent, frequency and some measures of intensity of fires have been studied over the past two decades, providing information on several features and trends.

5.2.4 References

Bittner Water Consult. 1999. Database for further decisions regarding the necessity and feasibility of future geophysical and hydrogeological investigations in the study areas Oshivelo, eastern Caprivi and eastern Tsumkwe-Otjinene (north-eastern Namibia). Department of Water Affairs, Windhoek.

Chakanga, M., Selänniemi, T. and Korhonen, K. 1999. Forest inventory report of Caprivi State Forest. Namibia Finland Forestry Programme, Directorate of Forestry, Windhoek.

Cole D. et al. 2014. Indigenous Plant Products in Namibia. Venture Publications. Windhoek.

East R. 1984. Rainfall, soil nutrient status and biomass of large African savanna mammals. Afr. J. Ecol, 22: 245-270.

Erkkilä, A. and Siiskonen, H. 1992. Forestry in Namibia, 1850-1990. Silva Carelica 20. University of Joensuu, Finland.

Gőrgen, M. and Gsänger, J. 2002. Gemeindewaldbewirtschaftung im Nordosten Namibias: Studie zur Wirtschaftlichkeit der Projektmaßnahmen. Report for Community Forestry Project in North-eastern Namibia, Directorate of Forestry, Windhoek.

Leffers, A. 2003. Gemsbok bean and Kalahari truffle: traditional plant use by Ju|'hoansi in north-eastern Namibia. Gamsberg Macmillan, Windhoek.

Mendelsohn, J.M. 2006. Farming systems in Namibia. RAISON, Windhoek.

Mendelsohn JM. 2013. Survey of Kavango Farms. Report for Ministry of Lands and Resettlement.

Mendelsohn JM and el Obeid S. 2002. The communal lands of eastern Namibia. RAISON, Windhoek.

Mendelsohn JM. and el Obeid S. 2003. Sand and Water: a profile of the Kavango region of Namibia. Struik, Cape Town.

Mendelsohn JM.and el Obeid S. 2005. Forests and woodlands of Namibia. RAISON, Windhoek.

Mendelsohn JM, Robertson T and A Jarvis. 2013. A profile and atlas of the Cuvelai-Etosha Basin. RAISON and Gondwana Collection, Windhoek.

Pröpper et al., 2010. Causes and perspectives of Land cover change through expanding cultivation in Kavango. In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Scholes RJ, Dowty PR, Caylor K and Parsons, DAB. 2002. Frost, P.G.H.3 and Shugart, H.H. 2002. Trends in savanna structure and composition along an aridity gradient in the Kalahari. Journal of Vegetation Science 13: 419-428, 2002

Strohbach BJ and Haarmeyer DH. 2010. Mile 46 (S01). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Strohbach BJ and Haarmeyer DH. 2010. Mutompo (S02). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Strohbach BJ and Haarmeyer DH. 2010. Sonop (S03). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Worbes. M. 1999. Growth of trees from Namibia - A dendrochronological study. Unpublished report for Namibia-Finland Forestry Project, Windhoek.

Yaron, G., Janssen, G and Maamberua, U. 1992. Rural Development in the Okavango Region of Namibia: An Assessment of Needs, Opportunities and Constraints. Windhoek, Gamsberg Macmillan.

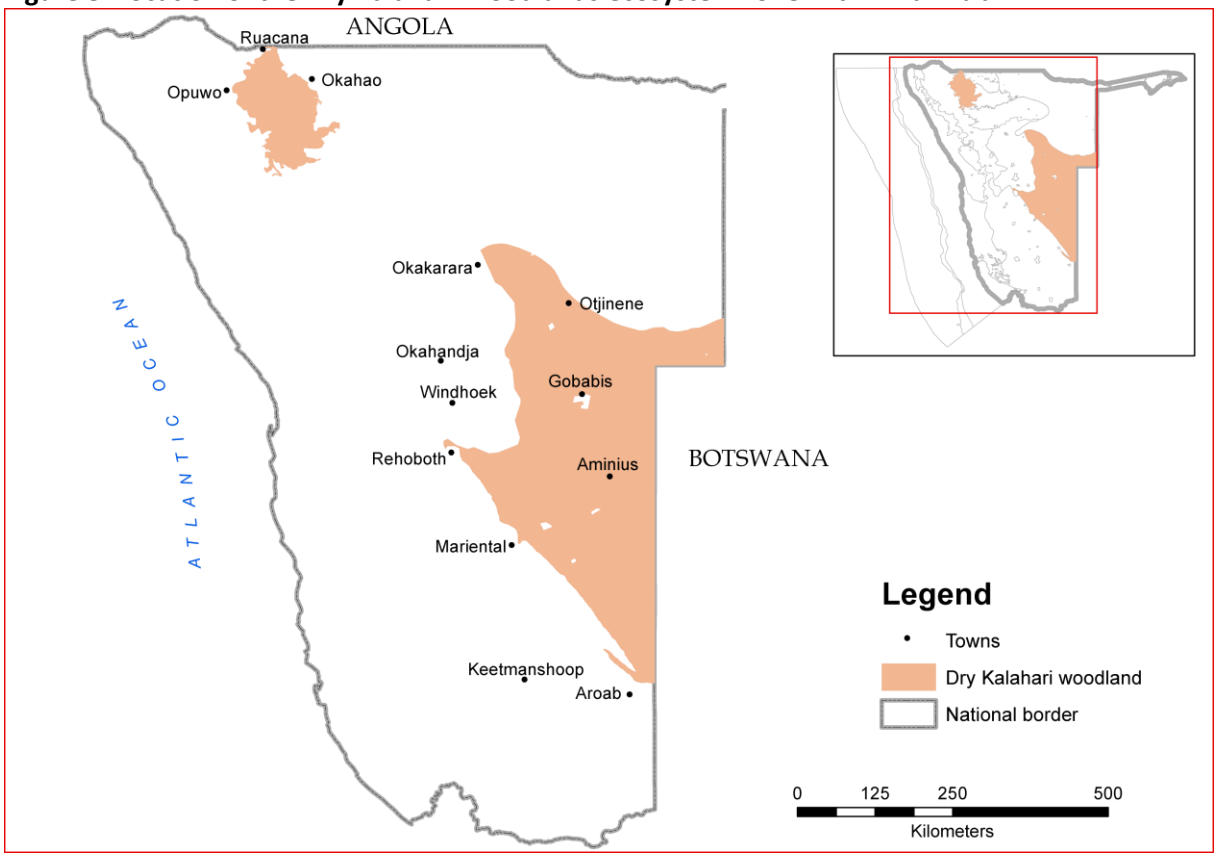
5.3 Dry Kalahari Woodlands

5.3.1 Description and assessment of ecosystem zone

5.3.1.1 Main attributes and ecological processes

The Dry Kalahari Woodlands is one of three major areas of aeolian sand in Namibia. It is comprised of two separate blocks: one in the east along the Botswana border, immediately to the south of the aeolian sands of the Northern Kalahari Woodlands, and the other in the Omusati region in the north-west of Namibia where the Cuvelai Drainage and Etosha Pans and Shrublands zones separate it from the Northern Kalahari Woodlands to the east. It covers a total of 134,000 km^2, and is presented in Figure 8.

Figure 8: Location of the Dry Kalahari Woodlands ecosystem zone within Namibia



The Dry Kalahari Woodlands is essentially a more arid version of the Northern Kalahari Woodlands. Both zones are extremely flat and largely covered with deep sand which is broken only in a few places by outcrops of basement rock, and by pans, dry water courses or inter-dune valleys that have fine-grained silt or clay soils. The Kalahari sands contain very few nutrients and their porous structure means that the sands hold little water. These characteristics render the sands unsuitable for cropping, particularly so in this more arid zone.

Average annual rainfall in the Dry Kalahari Woodlands ranges between 400mm in the northern and eastern areas, and 200mm in the far south. Perhaps surprisingly, annual vegetation production in the Dry Kalahari Woodlands zone is probably greater than in the wetter Northern Kalahari savanna. There are two likely reasons for this. Firstly, nutrients are leached by higher rainfall and thus lost to a

greater extent from the upper soil layers in the wetter northern zone. Secondly, because of more frequent fires, nutrients are blown away and lost in ash from the Northern Kalahari savanna.

As a result of its flat surface, aridity, and the sandy permeable soils, there are neither ephemeral nor perennial rivers in the zone. However, a number of fossil river courses remain from much wetter periods in the past. Examples are the White and Black Nossob 'Rivers' or *Omurambas*.

The zone's savanna vegetation is dominated by dense broadleaved bush, particularly *Terminalia sericea,* and *Acacia mellifera* in the north-western block and northern half of the eastern part of the zone. Grass cover in these areas is sparse. Many areas, especially those close to settlements with large cattle populations, are severely encroached with bush. The savanna is much more open further south, and is here dominated by *Acacia erioloba* and *Terminalia sericea*. The southern area of the zone has a distinct diversity of invertebrates.

5.3.1.2 Human activity and population

Gobabis is the only significant service and commercial centre in the dry Kalahari woodland, with an estimated population of 19,100 in 2011. This represents an increase of approximately 38% since 2001. Much smaller towns include Otjinene, Stampriet, Talismanus, Hoachanas, Epukiro, Gochas, Aranos and Aminius; all of these are in the eastern bloc of the Dry Kalahari Woodlands.

Rural populations in the Dry Kalahari Woodlands are estimated to have increased from 73,400 in 2001 to 78,300 in 2011 (6.7%). Population densities are low at approximately 0.58 people per km^2. The north-western block is almost entirely communal land, except for a small portion in the south that falls within Etosha National Park. Most residents in the north-west live in several villages, such as Uutsathima and Onamatanga, while most other people are herders of cattle.

Similar settlement patterns are found in the communal areas of the eastern bloc, for example between Otjinene and Talismanus and in the Aminius Block. The remaining areas are divided into freehold farms, each of which houses several labourers, the farm owner and their families.

The socio-economic characteristics of the eastern bloc of the Dry Kalahari Woodlands can be approximated by looking at the Omaheke region. Average consumption per capita in Omaheke is almost equal in both urban and rural areas, at around N$12,500; this is the fourth highest for rural areas in Namibia, but the fourth lowest for urban areas. Poverty incidence in the zone is the sixth highest in Namibia, with 21% of households classified as poor or severely poor. The north-western block largely falls within the Omusati, which has a consumption per capita that is slightly higher than the national average.

Parts of five conservancies are located within the ecosystem zone: Otjombinde, Otjituuo, Okamatapati, Ozonahi and African Wild Dog. There are no community forests or state protected areas in the zone.

5.3.1.3 Pressures and drivers of change

Table 17: Broad drivers of change and ecosystem-specific pressures in the Dry Kalahari Woodlands ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Overgrazing and fire control and prevention measures leading to bush encroachment
Exploitation	Abstraction of groundwater; harvesting of wood and INPs; increases in livestock numbers; wildlife offtake
Pollution	No relevant pressures in this zone
Invasive species	Prosopis along certain river valleys
Climate change	Potential to increase rate of bush encroachment; reduced rainfall
Illegal use	No relevant pressures in this zone

Table 17 relates the six broad categories of drivers of change to specific pressures within the Dry Kalahari Woodlands ecosystem zone. Habitat change is occurring primarily as a result of overgrazing, which in turn has a number of knock-on effects. Firstly, it results in damage to pastures and browse. Secondly, there are fewer and less intense fires. Thirdly, it encourages bush encroachment, which in turn reduces the rate of groundwater recharge.

The ecosystem-specific pressures relating to exploitation are very similar to those identified in the Northern Kalahari Woodlands ecosystem zone, although there are few crops in this zone, and less harvesting of wood. Livestock numbers have increased rapidly on communal land, especially over the last 10 years[40].

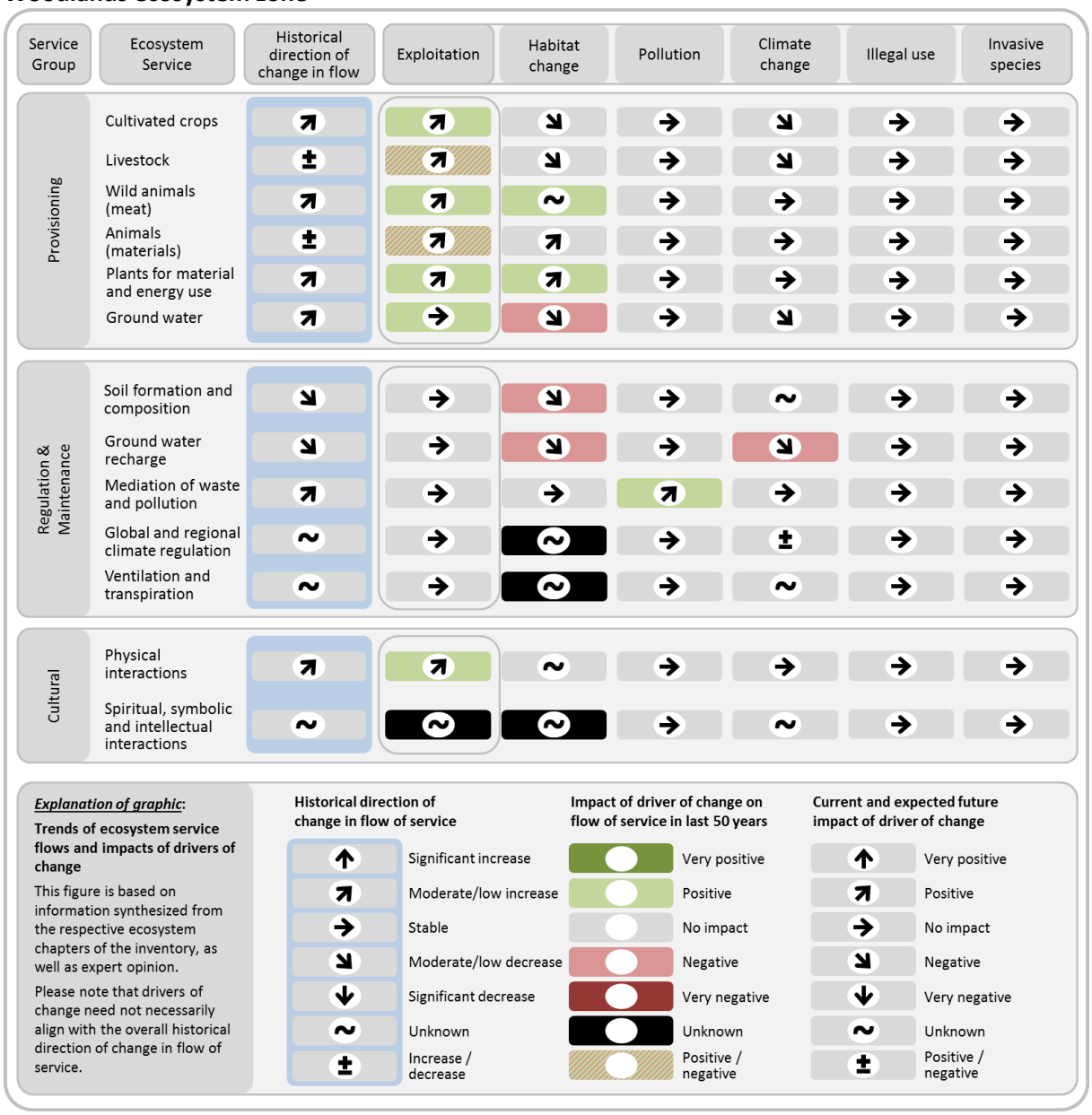
The effects of climate change may be realised through increased rates of bush encroachment and it could also result in reduced rainfall, but the extent of this is unclear. There are no relevant pressures relating to pollution or illegal uses of natural resources.

[40] Livestock census data compiled by Directorate of Veterinary Services

5.3.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Dry Kalahari Woodlands ecosystem zone. Figure 9 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 9: Overview of flows of services and impacts from drivers of change in the Dry Kalahari Woodlands ecosystem zone



5.3.2.1 Provisioning

Table 18 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Dry Kalahari Woodlands (and which are comparable to those classes specified in Figure 9). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 18: Overview of provisioning services in the Dry Kalahari Woodlands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Cultivated crops	Vegetables	National	Consumptive Use
Reared animals and their outputs	Meat and dairy products from livestock (cattle, goats, sheep)	National	Consumptive Use
Reared animals and their outputs	Livestock (cattle) as capital	National	Option
Wild animals and their outputs	Meat from wildlife	Local	Consumptive Use
Groundwater for drinking	Drinking water pumped from aquifers	Local	Consumptive Use
Fibres and other materials from plants, algae and animals for direct use or processing	Wool from sheep ; skins, horns and trophies from wildlife	International	Consumptive Use
Materials from plants, algae and animals for agricultural use	Fodder	Local	Consumptive Use
Groundwater for non-drinking purposes	Domestic water pumped from aquifers	Local	Consumptive Use
Groundwater for non-drinking purposes	Water for irrigation, livestock and wildlife pumped from aquifers	Local	Consumptive Use
Plant-based resources	Wood fuel; charcoal production; indigenous plant products (devil's claw, truffles, Tylosema etc)	National; local	Consumptive Use

Description

Farming with livestock and game is the dominant land use in the Dry Kalahari Woodland. Cattle and goats are favoured, except in the south-east where sheep (also used to produce wool) predominate. In the north-western block of the ecosystem zone, cattle are kept largely as capital. In the southern part of the ecosystem zone in particular, game is also farmed for meat and vegetables are grown commercially. Wildlife is also used to produce skins, horns and trophies.

Drinking water is pumped from aquifers; particularly productive aquifers are between Stampriet and the Botswana border. These aquifers are also used to provide water for domestic use, and for irrigation, livestock and wildlife. Groundwater in north-western Omusati is generally saline. Less significant services are the production of fodder, used as feed for livestock, charcoal production and the use of wood for fuel.

Affected population

Meat and dairy products and vegetables, as well as charcoal, are generally produced commercially in the zone and therefore are relevant to the national population. Livestock kept as cattle are also relevant to national populations as their owners often live outside of the zone. Other services are generally only relevant to local populations, with the exception being Karakul skins and trophies from wildlife, which are sold internationally.

Change in flow over past 50 years

Almost all of the provisioning services have increased in recent decades as a result of increased levels of exploitation; those growing at the fastest rates have probably been meat and dairy from goats, cattle-keeping and abstraction of water for livestock, wildlife and irrigation. The thickening of bush in the zone has helped to fuel the nascent charcoal industry. The only services not showing an increasing trend are the production of meat and dairy from cattle, which may have stabilised or declined slightly as a result of changing land uses towards wildlife and tourism, and farming Karakul wool, which declined drastically in recent decades as a result of the collapse of the international market price.

Pressures and expected impacts on flow of service

The exploitation of provisioning services relating to food is generally expected to continue growing at rates similar to recent decades. The farming of cattle is expected to broadly stabilise after some possible decline in recent decades, while continued strong growth in cattle-keeping in communal areas is expected.

There are wider negative pressures on many of these services, however. Land degradation from overgrazing and bush encroachment is reducing carrying capacity, and consequently the ability of the zone to support the production of livestock; the greatest impacts are likely to be on cattle farmers. To a lesser extent this may also impact on the production of meat from goats, sheep and wildlife (although the expansion of wildlife-based land uses could result in increased meat from wildlife). This habitat change could also represent a negative pressure on the production of vegetables if it limits the land available for this purpose, but a greater limiting factor to vegetable production is the availability of water.

Climate change may also negatively impact on availability of suitable land for these purposes if it increases the rate of bush encroachment. The production of crops may be limited in the future by nutrient availability when all arable areas have been exploited.

The exploitation of groundwater from drinking and domestic use is expected to broadly stabilise as a result of stabilising rural populations, and potentially greater access to piped water from outside of the zone. There may be increases in the abstraction of water for livestock, wildlife and irrigation if these services are further exploited. Habitat and climate change, principally through increased bush encroachment, may limit the capacity of the ecosystem zone to continue to provide growth in this service.

In recent years there has been some recovery in the Karakul market, and as a result this service is starting to increase again in the dry Kalahari Woodland. The exploitation of wildlife for skins, horns and trophies is expected to continue growing, albeit at a relatively slow rate.

The use of wood as a fuel is not expected to increase as rural populations stabilise, although increased bush may increase the potential for offtake. The production of charcoal in the zone is being driven by increased bush coverage, and exploitation of this resource is likely to increase.

5.3.2.2 Regulation and maintenance

Table 19 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Dry Kalahari Woodlands.

Table 19: Overview of regulation and maintenance services in the Dry Kalahari Woodlands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Filtration/sequestration/storage/ accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect Use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect Use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect Use
Ventilation and transpiration	Vegetation enabling air ventilation	Regional	Indirect Use
Weathering processes	Decomposition/mineralisation of dead organic material, nitrification	Local	Indirect Use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure	Local	Indirect Use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	International	Indirect Use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect Use

Description

The mediation of waste, toxins and other nuisances is generated largely at the ecosystem level by the absorption of pollutants and the dilution of gases into the atmosphere. The mediation of flows relates to both liquids, with regard to groundwater recharge, and gases, through vegetation enabling air ventilation. There are two groups of services relating to the maintenance of physical, chemical and biological conditions: soil formation and composition, (through both the decomposition/mineralisation of dead organic material and nitrification, as well as the maintenance of the fertility of soils, nutrient storage and their soil structure) and atmospheric composition and climate regulation (through carbon sequestration and the maintenance of regional precipitation/temperature patterns).

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of liquid and gaseous flows. The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level.

Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

The absorption and dilution of pollutants in the ecosystem zone is thought to have risen as a result of slightly increased pollution from higher populations and more human activity, although this is generally likely to be of limited importance. Increased coverage of bush in the zone is estimated to have reduced the rate of groundwater recharge. Overgrazing, clearing of woodland and fires in the ecosystem zone have resulted in a reduction in the flow of the soil formation and composition processes. The overall changes in carbon sequestration (due to potentially opposing impacts of loss of rangeland and increased bush), air ventilation, and micro and regional climate regulation are unknown.

Pressures and expected impacts on flow of service

The absorption and dilution of pollutants is expected to continue increasing at a similar rate as human activity in the ecosystem zone continues to grow, although it is still likely to be a relatively insignificant service. The rate of groundwater recharge is likely to be further reduced as bush encroachment continues; this could be compounded by climate change.

The negative effects from habitat change on soil formation and composition are also likely to continue, principally as a result of continued overgrazing and bush encroachment. Climate change may also impact on these processes.

There is uncertainty around the effects on carbon sequestration, as increased woody biomass as a result of bush encroachment could increase carbon sequestration, but habitat change that reduces available rangeland could reduce it. Climate change could also reduce regional precipitation, resulting in more arid conditions, but again it is unclear how significantly rainfall will decrease and over what time period it will occur.

5.3.2.3 Cultural

Table 20 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Dry Kalahari Woodlands.

Table 20: Overview of cultural services in the Dry Kalahari Woodlands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Wildlife viewing; landscape appreciation (e.g. red dunes of the Kalahari)	International	Non-consumptive use
Physical use of land-/seascapes in different environmental settings	Trophy hunting	International	Consumptive use
Scientific	Research on variety of topics	International	Consumptive use, non-consumptive use
Heritage, cultural	San; Tswanas; Resettlement farms; Hereroland	National	Non-consumptive use; existence; bequest
Symbolic	Relating to livelihoods, way of life, keeping cattle	National	Consumptive use; non-consumptive use; option
Sacred and/or religious	Relating to wildlife and landscapes; Hereroland	National	Non-consumptive use; existence; bequest
Existence	Relating to wildlife and landscapes; Hereroland	International	Existence
Bequest	Relating to wildlife and landscapes; Hereroland	International	Bequest

Description

Recreational tourism in the form of wildlife viewing, landscape appreciation (particularly of the red dunes of Kalahari) and recreational hunting occurs primarily on the freehold farms in the zone. The ecosystem zone also gives rise to scientific research on a range of topics.

Heritage, symbolic and cultural services occurring in the zone include those relating to the San people who live in the zone; the former designations of part of the area covered by the Dry Kalahari Woodlands as Hereroland and Tswanaland pre-independence; and broad services relating to livelihoods and the way of life. The San may also have specific rituals or sacred practices relating particularly to areas in the ecosystem zone. Existence and bequest services may be held relating to wildlife in the zone, as well as to livelihoods and ways of life and the designation of resettlement farms.

Affected population

Tourists to the zone are primarily international visitors; the ex-situ viewing of wildlife, scientific services and the existence and bequest services relating to wildlife are also relevant to international populations. The other services are all relevant to individuals living across Namibia.

Change in flow over past 50 years

Recreational tourism has increased in recent decades, although not as rapidly as in some other ecosystem zones; scientific services are also thought to have increased. The flow of services relating to other cultural services is not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone, particularly as the diversification towards wildlife as a land use continues. Habitat change could represent a threat in the longer term to recreational tourism, but currently this is of limited importance. The effects of pressures on other cultural services are generally poorly understood, but for example continued habitat change is likely to represent a negative pressure on the ways of life of the San.

5.3.2.4 Interactions between ecosystem zones and ecosystem services

Overgrazing and fire control measures in the ecosystem zone are resulting in land degradation (declines in the soil formation and composition services) and bush encroachment; the latter is in turn thought to be reducing the rate of groundwater recharge in the zone. The charcoal industry is being driven by bush encroachment, and there may also be positive effects on carbon sequestration from increased bush. The farming and keeping of livestock are in turn likely heavily linked with cultural services relating to ways of life for farmers, but conversely reduces the area over which the San are able to practice their own way of life and livelihoods.

5.3.3 Criteria for prioritisation of ecosystem services

5.3.3.1 Current and future expected impacts on the flow of the service

The provisioning services facing threats to their flow are cultivated crops, livestock and groundwater. With the exception of groundwater, the exploitation of these services is expected to continue growing, however. The services relating to soil formation and composition and groundwater recharge are also under increasing pressures.

5.3.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

There are limited threats from unsustainable water use in this ecosystem zone (the abstraction of groundwater is not thought to represent overexploitation).

Expansion of urban areas and increasing industrialisation

There are limited threats from industrialisation in this ecosystem zone.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the ecosystem zone to be used for agriculture, as well as the rate of groundwater recharge. There may be impacts on some cultural services (for example the ways of life of the San) but these are not well understood.

Rapid expansion of mining and prospecting

There are no threats from the rapid expansion of mining and prospecting in this ecosystem zone, although new copper mines are planned at Witvlei and Omitiomire.

Unsustainable land management practices

Overgrazing could be having significant impacts in the zone, resulting in land degradation, a reduction in the rate of groundwater recharge, and affecting some cultural services.

Uncontrolled bush fires

Bush fires are fewer and less intense than in the Northern Kalahari Woodlands, and there are more fire control measures in place as a result of the fencing off of private farms.

Alien invasive species

There are no significant threats from alien invasive species in this ecosystem zone, although local Prosopis infestations are likely to expand.

Illegal harvesting and trade of wildlife and forest and plant resources

There are no significant threats from poaching in this zone.

Human-wildlife conflict

Human-wildlife conflict could impact on recreational tourism if it negatively impacts on wildlife populations, and is an ongoing threat to livestock farming and crop production.

5.3.3.3 Economic importance (current and potential)

The commercial production of livestock in the zone is economically important. There is scope for growth in tourism but this is perhaps not as significant as in some other ecosystem zones.

5.3.3.4 Affected population (size and socio-economic characteristics)

Rural populations are relatively well-off in the zone (in comparison to rural populations in other zones), but they are likely to be affected via impacts on livestock and crop farming. Cultural services are possibly the most important for the poorest in the zone, such as the San.

5.3.3.5 Availability of data

The services with the greatest availability of data are likely to be marketed provisioning services (such as livestock and crops), as these transactions are registered and consequently the estimation of their flows is relatively simple. It should also be possible to obtain data for the number of tourists visiting the area.

5.3.4 References

Baird, J. 1995. Verification of socio-economic data for SARDEP test area in the southern and eastern communal areas. Report for Ministry of Agriculture, Water and Rural Development and Deutsche Gesellschaft für Technische Zusammenarbeit, Windhoek.

Botelle, A. and Rohde, R. 1995. Those who live on the land: a socio-economic baseline survey for land use planning in the communal areas of eastern Otjozondjupa. Report for Ministry of Lands, Resettlement and Rehabilitation, Windhoek.

Cole D. et al. 2014. Indigenous Plant Products in Namibia. Venture Publications. Windhoek.

International Development Consultancy. 2005. Study on land productivity and economic farming units. Report for the Ministry of Agriculture, Water and Forestry.

Kisopia, P. 1996. Community needs assessment in Omaheke – a participatory process. Report for Oxfam, Windhoek.

Kowalski, K. 1996. Overview of Omaheke's environmental situation. Report for Oxfam, Windhoek.

Mendelsohn, J.M. 2006. Farming systems in Namibia. RAISON, Windhoek.

Mendelsohn, JM 2015. Cuvelai-Etosha

Namibia Development Consultants. 2001. Regional Development Plans for Otjozondjupa and

Omaheke. Reports for National Planning Commission and Regional Governments of Otjozondjupa and Omaheke, Windhoek.

Social Science Division. 1994. Socio-economic survey: eastern communal areas. Report for Ministry of Agriculture, Water and Rural Development, Windhoek.

Strohbach, B.J. 2014. Vegetation of the Eastern Communal Conservancies in Namibia: I. Phytosociological descriptions. Koedoe - African Protected Area Conservation and Science, 56

Strohbach, B.J. 2014. Vegetation of the Eastern Communal Conservancies in Namibia: II. Environmental drivers. Koedoe - African Protected Area Conservation and Science, 56

Strohbach BJ and Haarmeyer DH. 2010. Sandveld (S41). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Suzman, J. 2000. Things from the bush: a contemporary history of Omaheke Bushmen. Basel Namibia Studies Series No. 5, P. Schlettwein Publishing, Switzerland.

Suzman, J. 2001. An assessment of the status of the San in Namibia. Legal Assistance Center, Windhoek.

Thomas, D.S.G., Twyman, C., 2004. Good or bad rangeland? Hybrid knowledge, science, and local understandings of vegetation dynamics in the Kalahari. Land Degradation and Development 15, 215–231.

Twyman C, Sporton D and DSG Thomas. Where is the life in farming? The viability of smallholder farming on the margins of the Kalahari, Southern Africa. Geoforum 35 (2004) 69–85.

Vigne, P. 2000. Options for livelihoods diversification in Omaheke region. Report for Oxfam Canada, Windhoek.

Werner, W. 1997. From communal pastures to enclosures: the development of land tenure in Herero reserves. Namibian Economic Policy Research Unit, Windhoek.

Werner, W., 1998. 'No One Will Become Rich'. Economy and Society in the Herero Reserves in Namibia, 1915–1946. P. Schlettwein, Basel (Switzerland).

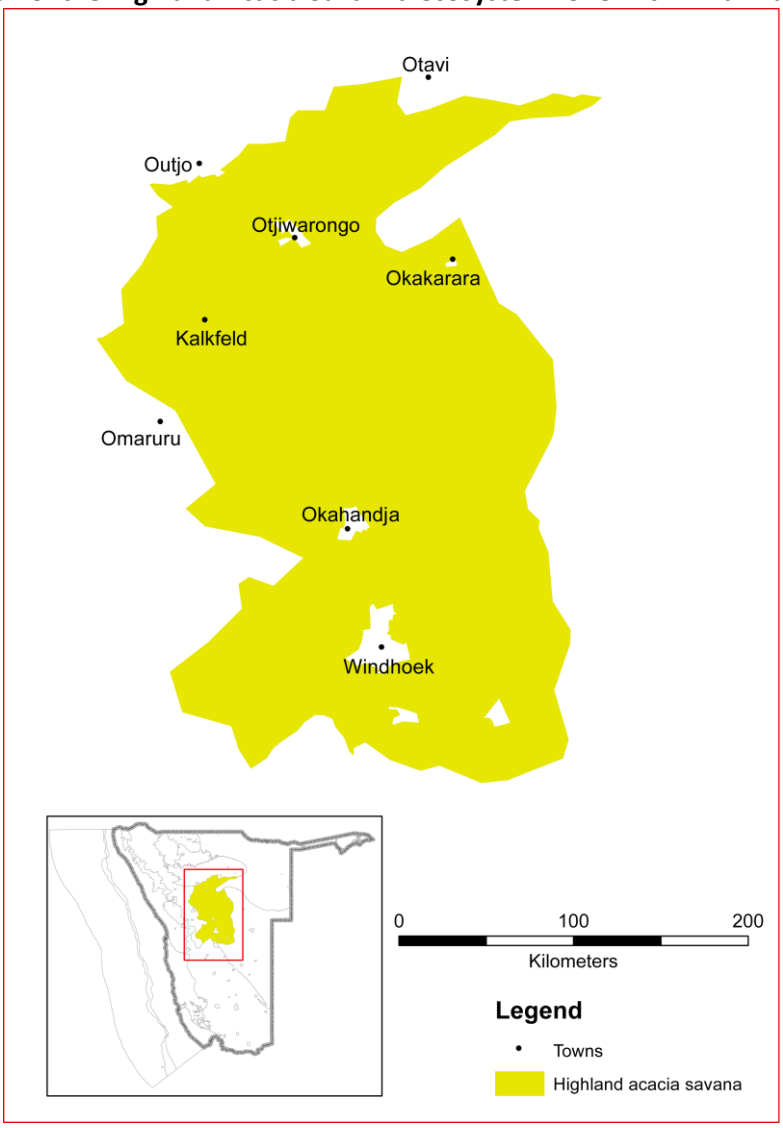
5.4 Highland Acacia Savanna

5.4.1 Description and assessment of ecosystem zone

5.4.1.1 Main attributes and ecological processes

The Highland Acacia Savanna encompasses 65,000 km^2 of central and north-central Namibia, and it is presented in Figure 10. Much of the zone lies on the metamorphic Damara Formation, which consists largely of schist and quartzite. Soils are typically shallow regosols and leptosols, being products of weathering of the local bedrock, and cambiosols. Cambiosols and arenosols (Kalahari Sands) cover much of the north-eastern and eastern areas of the zone, respectively.

Figure 10: Location of the Highland Acacia Savanna ecosystem zone within Namibia



The northern half of the zone consists of a gently rolling landscape between 1,300 and 1,500 metres above sea level, although isolated mountains (such as Mount Etjo, the Omatakos and the Paresis massif) that rise several hundred metres above their surroundings punctuate the even landscape in places. The southern half of the zone between Okahandja and just north of Rehoboth is more

dissected and rugged, with elevations ranging between 1,500 and 1,800 metres above sea level; the Auas mountains rise even higher, to above 2,200 metres.

The Highland Acacia Savanna is also characterised by its sparse savanna vegetation, consisting of acacia trees surrounded by grassland and patches of shrubland in most areas. Dominant trees are *Acacia mellifera, A. reficiens, A. hereroensis* and A. *erioloba*. Other abundant trees are *Ziziphus mucronata* and *Terminalia sericea* on sandy soils.

Five large ephemeral rivers have much of their catchments in the zone. These are the Ugab, Omaruru, Swakop, Omatako and Kuiseb Rivers. Other than the Omatako, all flow west and are fed by a great number of small tributaries which flow only sporadically, normally for short periods following heavy thunderstorms.

Most of the summer rains fall between December and March. Seasonal totals are variable, but usually amount to between 300 and 500 millimetres. Plant and animal production is driven by the amount of rain and its timing; production is highest in seasons when rain is abundant and falls at regular intervals. It is in these seasons that most groundwater is recharged.

Wildlife is diverse in this zone. Predators such as cheetah and leopard can be found on private reserves and farmland, alongside large numbers of different types of antelopes. There is a wide variety of range-restricted and endemic plants, reptiles (e.g. Waterberg sand lizard) and invertebrates in this zone, particularly associated with areas of higher altitude.

5.4.1.2 Human activity and population

Namibia's largest urban area, and capital, Windhoek, is located within the zone. Its population was estimated at 326,000 in 2011, an increase of almost 40% from 2001 (234,000). A number of other towns are also located within the Zone, principally Otjiwarongo, Okahandja and Okakarara; their combined population has increased by approximately 50% over the 10 years between 2001 to 2011 from 37,000 in 2001 to 56,000 in 2011. Other towns lie just outside the zone, such as Outjo, Otavi, Omaruru and Rehoboth.

Rural populations have declined from an estimated 60,000 in 2001 to 37,100 in 2011 (a reduction of almost 40%). This represents a fall in rural population densities from 0.92 to 0.57 people per km^2. The rural land principally includes freehold farms, with some freehold conservancies and private nature reserves (for example Erindi). The majority of farms are occupied by several families of labourers and often the owners, although a proportion of owners live elsewhere. Rural residents obtain goods and services from the local towns inside and just outside the zone.

The zone encompasses parts of Khomas and Otjozondjupa, both of which have average rural consumption per capita higher than the national average. The whole of the Ovitoto conservancy, as well as part of Ozonahi, falls within the ecosystem zone, but no community forests. A significant portion of the zone is covered by freehold conservancies. Daan Viljoen Game Park and Von Bach Recreation Resort are State Protected Areas which fall within the ecosystem zone. However they are small in size, accounting for just over 80 km^2.

5.4.1.3 Pressures and drivers of change

Table 21: Broad drivers of change and ecosystem-specific pressures in the Highland Acacia Savanna ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Overgrazing and fire control and prevention measures leading to bush encroachment; conversion of freehold farms to resettlement farms
Exploitation	Abstraction of groundwater; harvesting of game; increases in livestock numbers
Pollution	Pollution from industry and urban settlement (effluent and human waste) of watercourses; air emissions from vehicles and industry
Invasive species	Cactus and other alien species are common in and around Windhoek and may spread into this zone
Climate change	Potential to increase rate of bush encroachment
Illegal use	No relevant pressures in this zone

Table 21 relates the six broad categories of drivers of change to specific pressures within the Highland Acacia Savanna ecosystem zone. The pressures relating to habitat change are very similar to those in the Northern and Dry Kalahari Woodlands: overgrazing is reducing grass cover and available pasture, and, along with fire control and prevention measures, reducing the frequency and intensity of bush fires. This, in turn, is leading to increased bush encroachment, further reducing available pasture. The conversion of farms into resettlement farms has also affected the use of the land, the availability of pasture and the incidence of overgrazing.

Reduced grass cover is leading to increased surface run-off; after heavy rains this can be particularly rapid and results in soil erosion. Conversely, slower flows that had been sustained by seepage have declined because of reduced rainfall infiltration. Flows have also become limited by the zone's many farm dams and the large storage dams: von Bach and Swakoppoort (on the Swakop River) and the Omatako Dam.

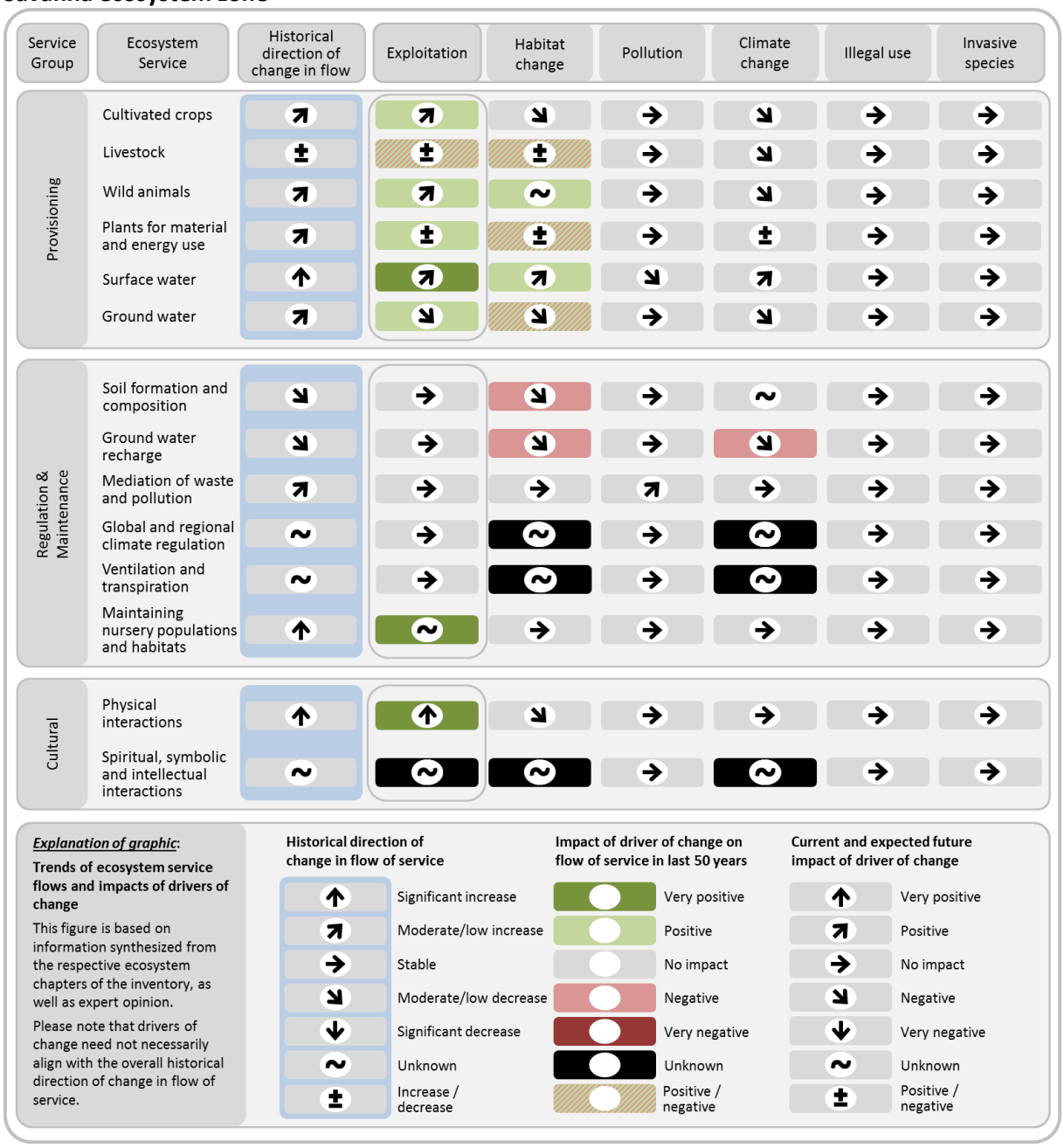
In some areas groundwater abstraction has exceeded rates of recharge, resulting in overexploitation of the groundwater resource. However, the main concern relating to groundwater is the effect of bush encroachment; consequently pressures on groundwater are anticipated to continue rising.

The effects of climate change may be realised through increased rates of bush encroachment. Pollution is a major pressure in the ecosystem zone: effluent from industry and human waste pollutes the Otjiseva River and subsequently feeds into the Swakop River and the Swakoppoort Dam; while industry and vehicles contribute to increasing levels of air pollution. Pollution from urban areas is a major local pressure in the ecosystem: effluent from industry and human waste pollutes the Otjiseva River and subsequently feeds into the Swakop River and the Swakoppoort Dam; while industry and vehicles contribute to increasing levels of air pollution.

5.4.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Highland Acacia Savanna ecosystem zone. Figure 11 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 11: Overview of flows of services and impacts from drivers of change in the Highland Acacia Savanna ecosystem zone



5.4.2.1 Provisioning

Table 22 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Highland Acacia Savanna (and which are comparable to those classes specified in

Figure 11). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 22: Overview of provisioning services in the Highland Acacia Savanna ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Cultivated crops	Maize, peanuts, sunflowers	National	Consumptive Use
Reared animals and their outputs	Meat and dairy products from livestock (cattle, goats)	National	Consumptive Use
Wild animals and their outputs	Meat from wildlife	National	Consumptive Use
Surface water for drinking	Drinking water from dams	National	Consumptive Use
Groundwater for drinking	Drinking water pumped from aquifers	Local	Consumptive Use
Fibres and other materials from plants, algae and animals for direct use or processing	Skins, horns and trophies from livestock and wildlife	International	Consumptive Use
Materials from plants, algae and animals for agricultural use	Fodder - blue buffalo grass	Local	Consumptive Use
Surface water for non-drinking purposes	Water for urban domestic use and industry from dams	National	Consumptive Use
Groundwater for non-drinking purposes	Water for domestic use, livestock and wildlife and irrigation pumped from aquifers	Local	Consumptive Use
Plant-based resources	Wood fuel	Local	Consumptive Use
Plant-based resources	Charcoal production	National	Consumptive Use

Description

Cattle ranching for beef production has been the dominant land use in the Highland Acacia Savanna for the past 100 years, occurring on the freehold farms in the zone. In the years since Independence, land uses have diversified to include a greater focus on wildlife, including farming for meat as well as the production of skins, horns and trophies. In the north-eastern areas of the zone, maize is grown on large dry-land fields of cambisol soils, which are also used to produce peanuts, sunflowers and fodder (such as Blue Buffalo grass). There is also some farming of small-stock, such as goats.

Drinking water is pumped from aquifers, as well as being drawn from dams that capture surface water flowing through the ephemeral rivers. The dams are also used to provide water for domestic use and industry, while groundwater is also pumped for livestock, wildlife and irrigation purposes. Bush in the zone is also being used to produce charcoal, while there is also offtake of wood for fuel.

Affected population

Meat and dairy products, cultivated crops and charcoal are generally produced commercially in the zone and therefore are relevant to the national population. Surface water from dams is ultimately used at a national level as it is piped to urban centres inside and outside the zone for drinking, domestic, commercial and industrial use. Groundwater from aquifers is primarily relevant to local

populations as it is usually used in the vicinity of its abstraction; this is also the case for wood fuel and fodder. Skins, horns and trophies from wildlife are exported internationally.

Change in flow over past 50 years

Almost all of the provisioning services in the Highland Acacia Savanna have increased in recent decades as a result of increased levels of exploitation; those growing at the fastest rates have been the provision of water from dams to rapidly growing urban populations. The thickening of bush in the zone has helped to fuel the nascent charcoal industry. The production of beef is perhaps the only service that has not increased in recent decades, as a result of a shift to more wildlife- and tourism-based land use, as well as some resettlement farms which are likely to be less productive than the freehold ones they replace.

Pressures and expected impacts on flow of service

The growth of the exploitation of cultivated crops is expected to fall as all arable land becomes exploited and capacity is reached, while the production of beef could continue to fall as a result of the ongoing shift towards wildlife-based land uses and the conversion of freehold farms to resettlement farms (this may in turn result in increased small-stock farming). Fodder production is expected to decline in line with beef production.

Habitat change is expected to represent a negative pressure on some of these services. Bush encroachment is reducing available pasture land for cattle, and could also restrict the further growth of farming cultivated crops. While bush encroachment may reduce available land for wildlife, the switch to wildlife based land uses could offset this, so the future impact is unclear. Habitat change is not likely to have a major impact on the production of meat from goats.

Climate change may also negatively impact on availability of suitable land for these purposes if it increases the rate of bush encroachment. The production of crops may be limited in the future by nutrient availability when all arable areas have been exploited.

The exploitation of groundwater for drinking water and domestic use is expected to decline slightly as rural populations in the zone decline, while its use for livestock, wildlife and irrigation is likely to stabilise. The exploitation of surface water from dams for drinking, domestic, commercial and industrial use is expected to continue growing in line with urban expansion but alternative water sources for Windhoek will have to be found outside this ecosystem zone (see the sections on North-Eastern Rivers and the Karstveld).

Industrial effluent and human waste is increasingly polluting watercourses and ultimately dams (in particular the Swakoppoort Dam). This will continue in line with industrialisation and the growth of informal settlements, and represents a further pressure on the provision of surface water for a variety of uses.

Habitat change has opposing effects on the provisioning services relating to groundwater and surface water. Bush encroachment tends to increase surface runoff and reduce the rate of groundwater recharge; however this increased surface runoff could in turn increase the recharge

rate of dams, and their ability to provide water. Climate change could further compound these effects by encouraging growth of woody biomass.

Greater densities of bush increase the potential for offtake for use as wood fuel. The production of charcoal in the zone is being driven by increased bush coverage, and exploitation of this resource is likely to increase.

5.4.2.2 Regulation and maintenance

Table 23 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Highland Acacia Savanna.

Table 23: Overview of regulation and maintenance services in the Highland Acacia Savanna ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect use
Ventilation and transpiration	Vegetation enabling air ventilation	Regional	Indirect use
Maintaining nursery populations and habitats	Private farms/freehold conservancies/nature reserves provide key habitat for wildlife	International	Indirect use
Weathering processes	Decomposition/mineralisation of dead organic material, nitrification	Local	Indirect use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure	Local	Indirect use
Chemical condition of freshwaters	Maintenance of condition of freshwater	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	International	Indirect use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect use

Description

Many of the zone's regulation and maintenance services take place at reduced rates and scales, given the arid environment. The mediation of waste, toxins and other nuisances is generated largely at the ecosystem level by the absorption of pollutants and the dilution of gases into the atmosphere. The mediation of flows relates to both liquids, with regard to groundwater recharge, and gases, through vegetation enabling air ventilation.

Relevant services in the maintenance of physical, chemical and biological conditions division are broader. They include soil formation and composition, (through both the decomposition/mineralisation of dead organic material and nitrification, as well as the maintenance of the fertility of soils, nutrient storage and their soil structure), atmospheric composition and climate regulation (through carbon sequestration and the maintenance of regional precipitation/temperature patterns), and the maintenance of habitats for wildlife, including threatened and endangered species such as cheetah and white rhino, on private farms, nature reserves and freehold conservancies (maintaining nursery populations and habitats). This division also includes the maintenance of chemical conditions of freshwater, particularly relating to dams and the rivers that flow into them.

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of liquid and gaseous flows and the maintenance of the chemical condition of freshwaters. The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level. The maintenance of habitats for wildlife is relevant internationally to the extent it supports internationally recognised and endangered species. Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

The absorption and dilution of pollutants in the ecosystem zone has increased as a result of greater pollution from bigger populations and more human activity. Pollution from industrial effluent and human waste in watercourses and dams has had a negative impact on the chemical condition of freshwater. Increased coverage of bush is estimated to have reduced the rate of groundwater recharge.

Overgrazing, clearing of woodland and fires in the ecosystem zone have resulted in a reduction in the flow of the soil formation and composition processes. The overall changes in carbon sequestration (due to potentially opposing impacts of loss of rangeland and increased bush), air ventilation, and micro and regional climate regulation are unknown. The importance of private farms and nature reserves as a critical habitat for threatened and endangered species has increased significantly in recent decades as a result of increasing use for this purpose.

Pressures and expected impacts on flow of service

The absorption and dilution of pollutants is expected to continue increasing due to ongoing expansion of human activity in urban areas. Further research is needed to understand the ongoing ability of the ecosystem zone to mediate this pollution. Pollution of watercourses and dams is also expected to continue as industries and informal settlements continue to grow. The rate of groundwater recharge is likely to be further reduced as bush encroachment continues; this could be compounded by climate change inducing further growth of woody biomass.

The negative effects from habitat change on soil formation and composition are also likely to continue, as a result of continued overgrazing and bush encroachment. Climate change may also impact on these processes.

It is also not clear how the service relating to the maintenance of nursery populations and habitats will change. Growth in the exploitation of the service will slow or even stop as much land has already been converted for wildlife-based land uses, but increased pressure from poaching could increase its importance in this regard.

There is uncertainty around the effects on carbon sequestration, as increased woody biomass as a result of bush encroachment could increase carbon sequestration, but habitat change that reduces available rangeland could reduce it. Climate change could also reduce regional precipitation, resulting in more arid conditions, but again it is unclear how significantly rainfall will decrease and over what time period it will occur.

5.4.2.3 Cultural

Table 24 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Highland Acacia Savanna.

Table 24: Overview of cultural services in the Highland Acacia Savanna ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Wildlife viewing, other recreational tourism	International	Non-consumptive use
Physical use of land-/seascapes in different environmental settings	Recreational hunting	International	Consumptive use
Scientific	Research on wildlife, bush and ecosystem processes in general	International	Consumptive use, non-consumptive use
Educational	Educational services from nature reserves, game parks	National	Non-consumptive use; existence; bequest
Heritage, cultural	Rehoboth (Basterland) homeland; resettlement farms	National	Non-consumptive use; existence; bequest
Aesthetic	Representations of isolated mountains in the zone e.g. Omatakos	International	Non-consumptive use
Existence	Relating to wildlife	International	Existence
Bequest	Relating to wildlife	International	Bequest

Description

Recreational tourism is an important cultural service in the Highland Acacia Savanna, particularly focusing on wildlife viewing and recreational hunting on a number of private game reserves. The

Otjiwarongo District has also been referred to as the "Cheetah Capital of the World"[41], where the threat of human-wildlife conflict has been turned into an opportunity for conservation and tourism. Scientific and education services relating to wildlife and their interactions with the ecosystem zone and human activity are generated through a number of institutions, private nature reserves and freehold conservancies in the ecosystem zone, while more general research also occurs on ecosystem processes in the zone.

The zone includes the northern part of what was the Rehoboth (or Basterland) homeland, which is also associated with heritage and broader cultural services. There are aesthetic services generated particular from representations of some of the isolated mountains in the zone (for example the Omatakos). Existence and bequest services may be held relating to wildlife in the zone, as well as to the designation of resettlement farms.

Affected population

Tourists to the zone are primarily international visitors; the scientific and the existence and bequest services relating to wildlife are also relevant to international populations. The other services are all relevant to individuals living across Namibia.

Change in flow over past 50 years

Recreational tourism has increased significantly in recent years, especially as freehold farms have increasingly converted to wildlife-based land uses. The flows of other cultural services in the zone are not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone. Habitat change could represent a threat in the longer term to recreational tourism, but currently this is of limited importance. The effects of pressures on other cultural services in the zone are generally poorly understood.

5.4.2.4 Interactions between ecosystem zones and ecosystem services

Overgrazing and fire control measures in the ecosystem zone are resulting in declines in the soil formation and composition services and bush encroachment, which reduces the rate of groundwater recharge. The switch to wildlife-based land uses could reduce pressures on pasture in some areas, but the designation of resettlement farms could increase it. The farming and keeping of livestock are also likely heavily linked with cultural services relating to ways of life for farmers.

The charcoal industry is being driven by bush encroachment, and there may also be positive effects on carbon sequestration from increased bush. Pollution of watercourses and eventually dams (impacting the maintenance of condition of freshwaters) could affect the provisioning of surface water for a number of different uses.

[41] http://www.travelnewsnamibia.com/featured-stories/otjiwarongo-cheetah-capital-of-the-world/

5.4.3 Criteria for prioritisation of ecosystem services

5.4.3.1 Current and future expected impacts on the flow of the service

The provisioning services of livestock and groundwater (as a result of habitat change through bush encroachment and the impacts of climate change) and surface water (due to overexploitation primarily as a result of growing demand from Windhoek) all face threats to their continued flow. The regulation and maintenance services relating to soil formation and composition and groundwater recharge are also under increasing pressures from bush encroachment and climate change.

5.4.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

The growth in demand for surface water from dams in the ecosystem zone, primarily from urban areas such as Windhoek, is unsustainable. Additionally, climate change could potentially result in greater variability in annual rainfall and lower average annual rainfall, reducing the recharge rates of the dams. Water supply sources outside of the ecosystem zone (such as from the NE Rivers or groundwater from the Karstveld) are therefore being explored as possibilities to meet this growing demand. The provisioning of surface water also faces pressure from increased pollution, particularly through industrial effluent and human waste from the growth in informal settlements.

Expansion of urban areas and increasing industrialisation

Windhoek's population is growing rapidly as is its industrial footprint, particularly in the northern industrial area and the Brakwater area just north of Windhoek, which is evolving from a series of smallholdings to a more industrial area. The major threats from this urban expansion and industrialisation relate to pollution, in terms of the extent to which the ecosystem zone can absorb and/or dilute the pollutants; and the pollution of watercourses which could place pressure on the provisioning of water from dams. There are also impacts from noise and visual pollution. Depending on the type and location of industry, there may be increased threats to groundwater, which could in turn impact on the delivery of groundwater as a provisioning service. These threats will also be experienced around other towns in the ecosystem zone, but to a lesser extent given their significantly smaller size.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the ecosystem zone to be used for agriculture, as well as the rate of groundwater recharge.

Rapid expansion of mining and prospecting

There are no significant threats from the rapid expansion of mining and prospecting in this ecosystem zone.

Unsustainable land management practices

Overgrazing could be resulting in land degradation, reducing the rate of groundwater recharge, as well as affecting some cultural services. The incidence of overgrazing varies significantly within the zone.

Uncontrolled bush fires

Uncontrolled bush fires are not thought to be a threat in this ecosystem zone.

Alien invasive species

There are no significant threats from alien invasive species in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

There are no significant threats from poaching in this zone.

Human-wildlife conflict

Human-wildlife conflict in the zone is fairly limited; there may be some offtake of livestock by predators but these are often tolerated as a result of their tourism value.

5.4.3.3 Economic importance (current and potential)

Recreational hunting and tourism is of economic importance to a great deal of the private farms and reserves in the zone. The commercial production of livestock and crops is also economically significant to those farms and to Namibia more widely. The provision of water, particularly to urban centres, is also crucial. Given the bush encroachment in this area, there are potential benefits from the use of woody biomass, such as for electricity generation.

5.4.3.4 Affected population (size and socio-economic characteristics)

The provision of water to urban centres is the service that affects the most individuals in the zone. Rural residents are comparatively well-off in the zone; the most important service to them is likely the farming of livestock and crops, and the regulating services that enable this.

5.4.3.5 Availability of data

The services with the greatest availability of data are likely to be marketed provisioning services (such as livestock and crops), as these transactions are registered and consequently the estimation of their flows is relatively simple. It should also be possible to monitor the usage and quality of water from dams and air quality. Some estimate of wildlife numbers should be available from the private reserves and farms that operate in the ecosystem zone, along with the number of tourists visiting and staying in different types of accommodation.

5.4.4 References

Bester, F.V 1999. Major problem: bush species and bush densities in Namibia. Agricola 10: 1-3.

Bond, W.J., Midgley, G.F. and Woodward, F.I. 2003. The importance of low atmospheric CO2 and fire in promoting the spread of grasslands and savannas. Global Change Biology 9: 973-982.

Bond, W.J., Midgley, G.F. and Woodward, F.I. 2003. What controls South African vegetation – climate or fire? South African Journal of Botany. 69: 79-91.

Colin Christian and Associates CC. 2010. The Effect of Bush Encroachment on Groundwater Resources in Namibia: a Desk Top Study. Report for the Namibian Agricultural Union, Windhoek.

De Klerk, N. 2004. Bush encroachment in Namibia. Ministry of Environment and Tourism.

Gröngröft A, Grohmann C and Haarmeyer DH. 2010. Toggekry (S04). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Gröngröft A, Grohmann C and Haarmeyer DH. 2010. Otjiamongombe (S05). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Jeltsch et al., 2010. Impacts of landuse and climate change on the dynamics and biodiversity in the Thornbush Savanna Biome. In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Joubert, D.F., Rothauge, A. and Smit, G.N. 2008. A conceptual model of vegetation dynamics in the semiarid Highland savanna of Namibia, with particular reference to bush thickening by Acacia mellifera. Journal of Arid Environments, 72(12): 2201-2210

Mendelsohn, J.M. 2006. Farming systems in Namibia. RAISON, Windhoek.

Ministry of Agriculture, Water and Forestry. 2014. A pre-feasibility study into the augmentation of water supply to the central area of Namibia and the Cuvelai. Windhoek, Namibia.

Strohbach BJ and Haarmeyer DH. 2010. Claratal (S38). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Ward, D., Ngairorue, B.T., Apollus, A., Tjiveze, H., 2000. Perceptions and realities of land degradation in arid Otjimbingwe, Namibia. Journal of Arid Environments 45, 337–356.

Wesuls D and Haarmeyer DH. 2010. Okamboro (S06). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Wesuls D and Haarmeyer DH. 2010. Narais (S39). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Wesuls D and Haarmeyer DH. 2010. Duruchaus (S40). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

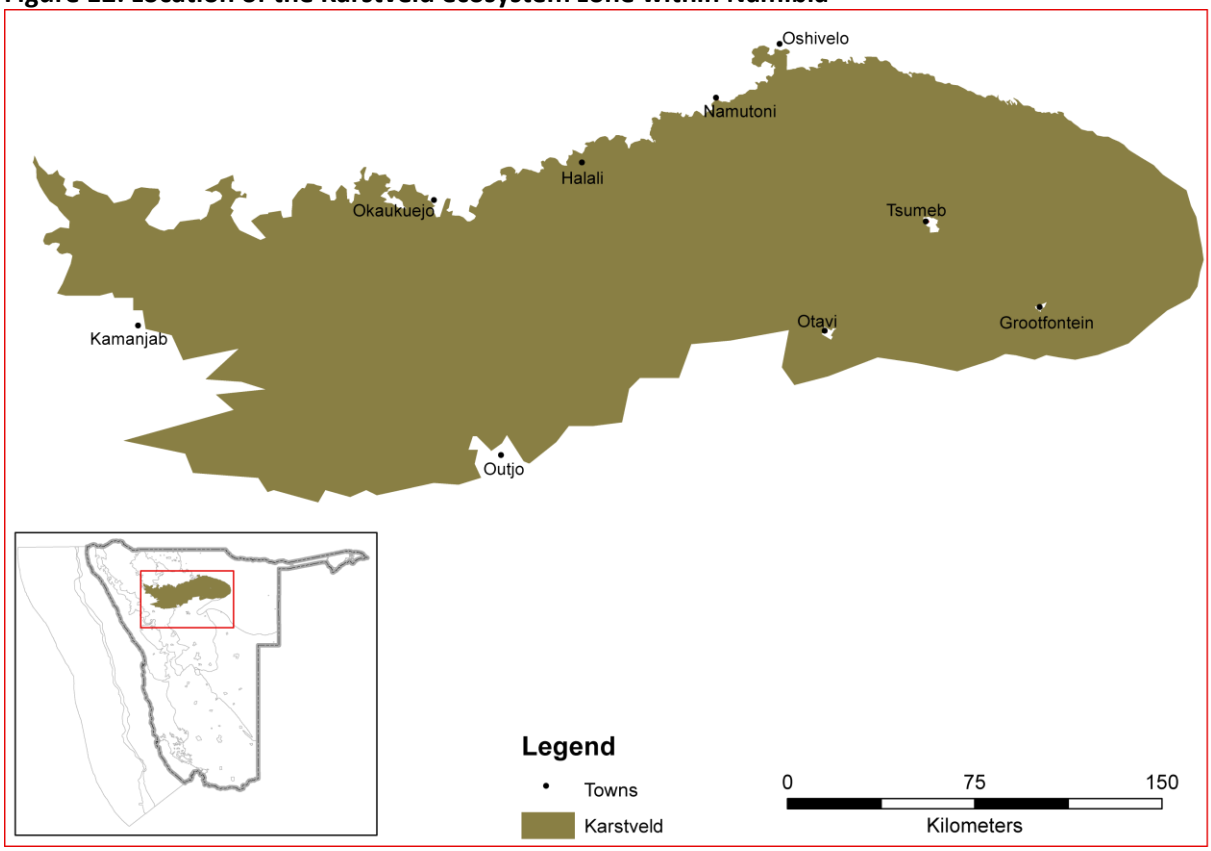
5.5 Karstveld

5.5.1 Description and assessment of ecosystem zone

5.5.1.1 Main attributes and ecological processes

The Karstveld ecosystem zone (Figure 12) is a belt of 42,300 square kilometres of north-central Namibia, lying directly to the north of the Highland Acacia Savanna.

Figure 12: Location of the Karstveld ecosystem zone within Namibia



The zone consists of metamorphic limestone and dolomite hills and soils formed largely as products of erosion from these karst carbonate rocks. The belt formed from shallow marine sediments that were uplifted during the formation of the Gondwana continent about 850 million years ago. The carbonate rocks are highly soluble which has led to the formation of large underground cavities and aquifers filled and recharged with water from local rainfall. The Karstveld is therefore relatively rich in groundwater.

Its eastern hilly areas, also known as the Tsumeb-Grootfontein-Otavi Triangle, receive comparatively more rain than do surrounding lowlands. This is a consequence of orographic uplift causing rain to fall over the hills that generally rise about 200-300 metres above the lowlands. Average annual rainfall over the highlands is over 500 millimetres, about 50-100 more than in the lowlands and up to 200 mm more than in the drier, western areas of Zone. Rainfall drives most plant and animal production, which is highest in seasons when rain is abundant and falls at regular intervals.

The karst hills are typically covered in broad-leaved, deciduous woodlands, while the surrounding lowlands in the east are dominated by *Acacias*, *Terminalia prunioides* (purple-pod terminalia) and

Dichrostachys cinerea (sekelbos). Mopane is the dominant plant in the western lowlands, in many areas being almost the only woody species. Bush encroachment is severe in the eastern lowlands, particularly on fallow land.

Leptosols are the most abundant soils in the eastern and western lowlands. Much calcrete has formed in the soils especially in moister areas. In and around the hill in the east of the Zone are areas of cambisols and luvisols. In combination with good rainfall, these are more suited to arable farming than most other soils in Namibia. There are no significant rivers in the Karstveld.

The parts of the zone that fall within Etosha National Park are home to a variety of large mammals, including elephant, rhino (white and black) and giraffe. Predators such as lion, leopard and cheetah are also found in the zone, extending to the private farms and game reserves to the south of Etosha. The Karstveld is home to endemic, range-restricted, and endangered plants, reptiles, freshwater fish and invertebrates.

5.5.1.2 Human activity and population

The four largest towns in the Karstveld are Tsumeb, Grootfontein, Outjo and Otavi. Collectively, their populations have increased by 27% to 50,000 between 2001 and 2011. Urban populations in this zone are generally growing more slowly than in other ecosystem zones.

As with the neighbouring Highland Acacia Savanna ecosystem zone, rural populations in the Karstveld fell by almost 40%, from 37,200 to 23,700 between 2001 and 2011. Rural population densities in the Karstveld are similar to those in the Highland Acacia Savanna, at approximately 0.56 people per km^2.

The south-eastern third of Etosha National Park lies in the Karstveld. Much of the rural land outside of Etosha in the Karstveld is private freehold farmland or nature conservation areas. The socio-economic characteristics of the population within the zone are difficult to estimate as it does not really correspond to an administrative region, falling partly within each of Kunene, Otjozondjupa and Oshikoto.

Outside Etosha National Park, most rural areas are used for beef and game meat production and tourism. The irrigated production of fruit, maize, sunflower, fodder, vegetables and other assorted crops characterises the Tsumeb-Grootfontein-Otavi Triangle. Cement is produced at Ohorongo while copper has been mined at various sites.

5.5.1.3 Pressures and drivers of change

Table 25: Broad drivers of change and ecosystem-specific pressures in the Karstveld ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Overgrazing, fire control and prevention measures and clearing of land for crops leading to bush encroachment; conversion of freehold farms to resettlement farms
Exploitation	Abstraction of groundwater; harvesting of game and crops
Pollution	No relevant pressures in this zone
Invasive species	No relevant pressures in this zone, but the higher rainfall in the Zone increases the chances that alien plants could become invasive
Climate change	Potential to increase rate of bush encroachment; reduced rainfall
Illegal use	Poaching, particularly of rhino within Etosha and neighbouring land to the south

Table 25 relates the six broad categories of drivers of change to specific pressures within the Karstveld ecosystem zone. Overall, the pressures are similar to the Highland Acacia Savanna ecosystem zone. Habitat change is occurring as a result of overgrazing, which reduces grass cover and available pasture, and fire control and prevention measures. In addition, significant areas of land have been cleared for crops. This, in turn, is leading to increased bush encroachment, further reducing available pasture and increasing surface runoff and soil erosion in some areas. The conversion of farms into resettlement farms has also affected the use of the land, the availability of pasture and the incidence of overgrazing.

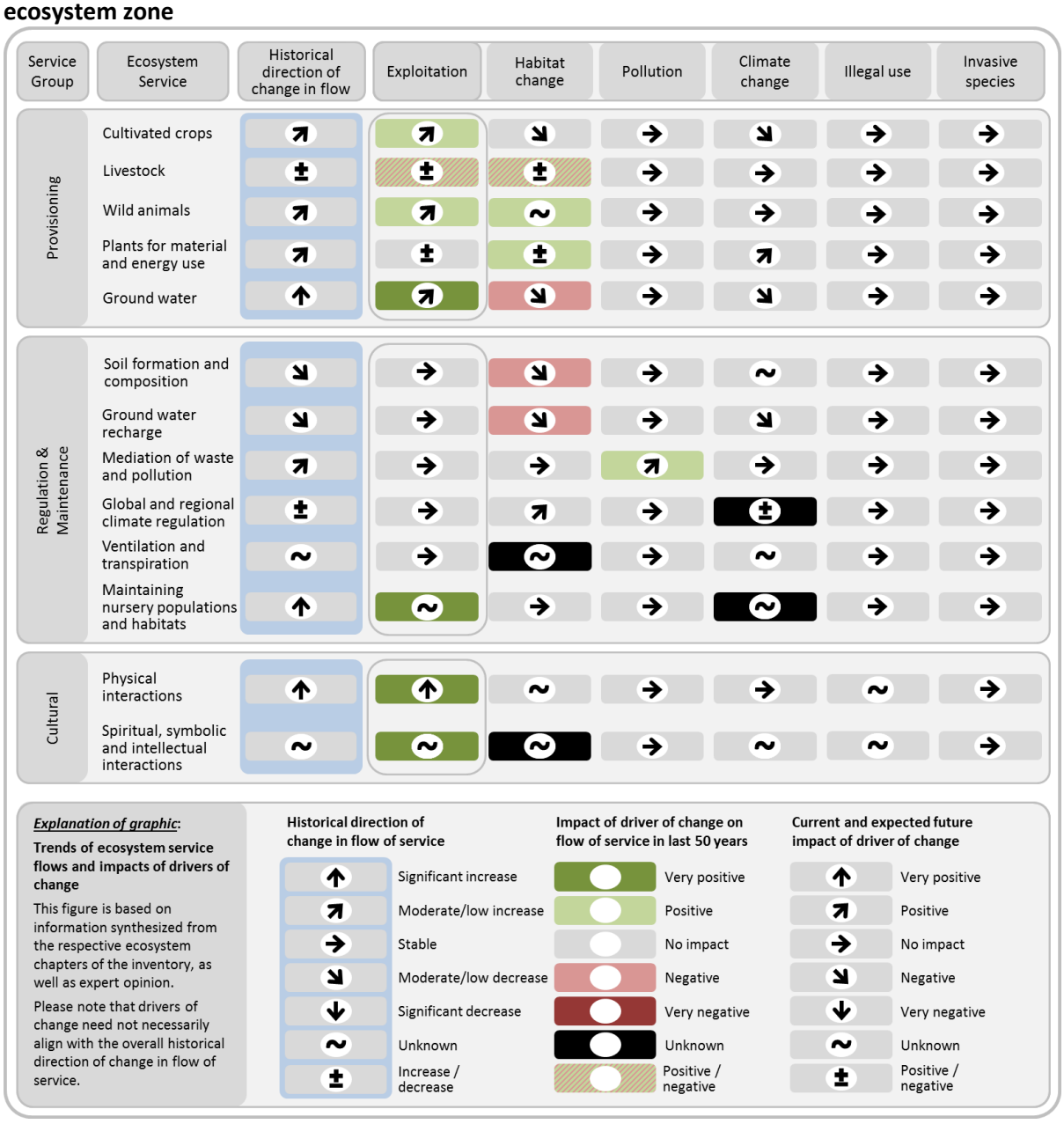
The degree to which groundwater levels have fallen varies from one area to another, due to different rates of harvesting, degrees of bush encroachment, the size of local aquifers and the ease with which they are recharged. In some areas, however, it is thought there has been overexploitation of the groundwater resource; it is apparent that significant recharge only occurs in years with above average rainfall.

Poaching in Etosha has increased significantly in recent years; this is discussed in more detail in Section 5.5.4. The effects of climate change may be realised through increased rates of bush encroachment. Pressures emanating from towns, such as pollution, groundwater use and potentially invasive plants are largely confined to the Urban ecosystem zone in which the towns fall (see Section 5.16.4). Outside these areas, there are few relevant pressures relating to pollution or invasive species. In general, no major change to the functioning of the zone is anticipated.

5.5.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Karstveld ecosystem zone. Figure 13 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 13: Overview of flows of services and impacts from drivers of change in the Karstveld ecosystem zone



5.5.2.1 *Provisioning*

Table 26 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Karstveld (and which are comparable to those classes specified in Figure 13). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 26: Overview of provisioning services in the Karstveld ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Cultivated crops	Cereals and other commercial crops	National	Consumptive use
Reared animals and their outputs	Meat and dairy from livestock (cattle, goats)	National	Consumptive use
Wild animals and their outputs	Meat from wildlife	National	Consumptive use
Groundwater for drinking	Drinking water pumped from aquifers	Local; regional	Consumptive use
Fibres and other materials from plants, algae and animals for direct use or processing	Skins, horns and trophies from livestock and wildlife	International	Consumptive use
Materials from plants, algae and animals for agricultural use	Fodder	Local	Consumptive use
Groundwater for non-drinking purposes	Water for domestic use, mining, livestock and wildlife, and irrigation pumped from aquifers	Local; regional	Consumptive use
Plant-based resources	Wood fuel	Local	Consumptive use
Plant-based resources	Charcoal production	National	Consumptive use

Description

In combination with the comparatively good rainfall over the highlands of the zone, the soils are more suited to arable farming than most other areas in Namibia, and thus much of the country's commercial production of cereals comes from this zone (also known as the Tsumeb-Grootfontein-Otavi Maize Triangle). Cattle farming has also been a significant land use in the zone for many years, but as in the Highland Acacia Savanna, there has been a growing focus on wildlife-based land uses in the years following independence (including harvesting meat and the production of skins, horns and trophies). Fodder is also produced in the zone.

Drinking water is pumped from aquifers; these sources are also used to provide water for mining, irrigation, livestock and wildlife. Bush in the zone is also being used to produce charcoal, while there is also offtake of some wood for fuel.

Affected population

Most meat and dairy products, cultivated crops and charcoal are produced commercially in the zone and therefore are relevant to the national population. Abstracted groundwater benefits national populations; water extracted at Berg Aukas north of Grootfontein is pumped into the Eastern National Water Canal which supplies water to farms and towns in the former eastern Hereroland. The canal ends in the Omatako dam from where water is pumped to augment supplies for Windhoek.

Wood fuel and fodder are generally used in the vicinity of their harvesting or production, and consequently are relevant to local populations. Skins, horns and trophies from wildlife are exported internationally.

Change in flow over past 50 years

Almost all of the provisioning services in the Karstveld have increased in recent decades as a result of increased levels of exploitation; the services growing at the fastest rates have been related to the provision of water, particularly for mining. The thickening of bush in the zone has helped to fuel the nascent charcoal industry and one electricity producer. The production of beef is perhaps the only service that has not increased in recent decades, as a result of a shift to more wildlife-based land uses, as well as some resettlement farms which are often less productive than the freehold ones they replace.

Pressures and expected impacts on flow of service

The exploitation of provisioning services relating to food is generally expected to continue growing at similar rates as in recent decades. Production of beef could continue to fall as a result of the ongoing shift towards wildlife-based land uses and the conversion of freehold farms to resettlement farms (which in turn may lead to greater farming of small stock).

Bush encroachment is reducing available pasture land for cattle. While bush encroachment may reduce available land for wildlife, the switch to wildlife based land uses could offset this, so the future impact on meat from wildlife is unclear. Climate change may also negatively impact on availability of suitable land for these purposes if it increases the rate of bush encroachment. The production of crops may be limited in the future by nutrient availability when all arable areas have been exploited.

The exploitation of groundwater for drinking water and domestic use is expected to decline slightly at the local level as rural populations in the zone fall, while its use for livestock, wildlife and irrigation is expected to stabilise or slightly decrease. Overall exploitation of groundwater could increase, however, as demand for water from Windhoek continues to grow and the pumping of more water from the Karstveld to meet this demand becomes a greater possibility. The exploitation of water for mining is expected to continue growing. Bush encroachment is likely to reduce the capacity of the zone to provide groundwater. Climate change could further compound these effects by encouraging growth of woody biomass.

The use of wood as a fuel is not expected to rise as rural populations stabilise, although denser bush may increase the potential for offtake for this purpose including for the electricity generation. The production of charcoal in the zone is being driven by increased bush coverage, and exploitation of this resource is likely to increase.

5.5.2.2 Regulation and maintenance

Table 27 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Karstveld.

Table 27: Overview of regulation and maintenance services in the Karstveld ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect use
Ventilation and transpiration	Vegetation enabling air ventilation	Regional	Indirect use
Maintaining nursery populations and habitats	Etosha as key conservation area	International	Indirect use
Weathering processes	Decomposition/mineralisation of dead organic material, nitrification	Regional	Indirect use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	International	Indirect use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances is generated largely at the ecosystem level by the absorption of pollutants and the dilution of gases into the atmosphere. The mediation of flows relates to both liquids, with regard to groundwater recharge, and gases, through vegetation enabling air ventilation.

Relevant services in the maintenance of physical, chemical and biological conditions division are more broadly defined. Soil formation and composition (through the decomposition/mineralisation of dead organic material and nitrification as well as the maintenance of the fertility of soils, nutrient storage and their soil structure) and atmospheric composition and climate regulation (through carbon sequestration and the maintenance of regional precipitation/temperature patterns) are key services. Etosha represents a key conservation area in Namibia, supporting, for example, white and black rhino, elephant, lion, leopard and cheetah (maintaining nursery populations and habitats).

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of liquid and gaseous flows. The services within the soil formation and composition group are primarily relevant to local populations as they support activities that occur on a local level.

Etosha as a key conservation area is relevant internationally. Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

The absorption and dilution of pollutants in the ecosystem zone is thought to have increased as a result of slightly increased pollution from higher populations and more human activity, although this is generally likely to be of limited importance. Increased coverage of bush in the zone is estimated to have reduced the rate of groundwater recharge.

Overgrazing and clearing of woodland in the ecosystem zone have resulted in a reduction in the flow of the soil formation and composition processes. The overall changes in carbon sequestration (due to potentially opposing impacts of loss of rangeland and increased bush), air ventilation, and micro and regional climate regulation are unknown. The importance of Etosha as a conservation area has risen significantly in recent decades as a result of its increased use for tourism.

Pressures and expected impacts on flow of service

The absorption and dilution of pollutants is expected to continue increasing at a similar rate as human activity in the ecosystem zone continues to grow, although it is still likely to be a relatively insignificant service. The rate of groundwater recharge is likely to be further reduced as bush encroachment continues; this could be compounded by climate change inducing further growth of woody biomass.

The negative effects from habitat change on soil formation and composition are also likely to continue, as a result of continued overgrazing and bush encroachment. Climate change may also impact on these processes.

It is not clear how the service relating to Etosha as a conservation area will change but it is likely to face increasing pressure from poaching.

There is uncertainty surrounding the effects on carbon sequestration, as bush encroachment could increase carbon sequestration, but habitat change that reduces available rangeland could reduce it. Climate change could also reduce regional precipitation, resulting in more arid conditions, but again it is unclear how significantly rainfall will decrease and over what time period it will occur.

5.5.2.3 Cultural

Table 27 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Karstveld.

Table 27: Overview of cultural services in the Karstveld ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Wildlife viewing, recreational tourism	International	Non-consumptive use
Physical use of land-/seascapes in different environmental settings	Recreational hunting	International	Consumptive use
Scientific	Etosha; other research e.g. bush encroachment	International	Consumptive use, non-consumptive use
Educational	Etosha	National	Non-consumptive use; existence; bequest
Heritage, cultural	Hei/Om	National	Non-consumptive use; existence; bequest
Entertainment	Ex-situ viewing of wildlife - Etosha	International	Non-consumptive use
Aesthetic	Representations of wildlife viewing in Namibia	International	Non-consumptive use
Symbolic	Etosha and wildlife as symbolic of Namibia	International	Non-consumptive use
Existence	Relating to wildlife; livelihoods and ways of life	International	Existence
Bequest	Relating to wildlife; livelihoods and ways of life; resettlement farms	International	Bequest

Description

Recreational tourism is an important cultural service in the Karstveld. Although much of the Etosha National Park within the Karstveld is off limits to tourists, it still represents a crucial part of the habitat that supports the wildlife that people go to see. Furthermore, there are a significant number of private tourism establishments and wildlife reserves to the south and east of the gates to Etosha which support visits from large numbers of tourists every year. There is also some recreational hunting in these private areas. Etosha contributes a great deal to scientific research and educational activities (for example the Etosha Ecological Institute), while also being symbolic of Namibia. Less significantly, it also contributes to the ex-situ viewing of wildlife and aesthetic services of representations of wildlife viewing in Namibia.

Lake Guinas and Lake Otjikoto were underground lakes until the roof of overlying rock collapsed to expose them as attractions for tourists.

The Karstveld is home to the majority of the Hei/Om population in Namibia, the largest subgroup of the Namibian San people; the Karstveld therefore likely represents heritage and cultural (and possibly sacred) services. Existence and bequest services may be held relating to wildlife in the zone, as well as to the designation of resettlement farms.

Affected population

Tourists to the zone are primarily international visitors; the scientific services and the existence and bequest services relating to wildlife are also relevant to international populations. The other services are all relevant to individuals living across Namibia.

Change in flow over past 50 years

Recreational tourism has increased significantly in recent years, not only as a result of the development of tourism facilities within Etosha, but also outside the park, where private land has increasingly been converted to wildlife-based land uses. Scientific services, education, the ex-situ viewing of wildlife and aesthetic and symbolic services are also thought to have increased substantially in recent decades. The flows of other cultural services in the zone are not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone. A more significant pressure could be poaching, but it is not currently at a level where it is likely to affect tourism. The effects of pressures on other cultural services in the zone are poorly understood.

5.5.2.4 Interactions between ecosystem zones and ecosystem services

Overgrazing and fire control measures in the ecosystem zone are resulting in land degradation (declines in the soil formation and composition services) and bush encroachment, which in turn reduces the rate of groundwater recharge. The switch to wildlife-based land uses could reduce pressures on pasture in some areas, but the designation of resettlement farms could increase it. The charcoal industry is being driven by bush encroachment, and there may also be effects on carbon sequestration from increased bush. The farming and keeping of livestock is also likely heavily linked with cultural services relating to ways of life for farmers. As part of this zone falls within Etosha there is a clear link between this zone and the Etosha Pans and Shrublands zone.

There are also linkages between urban areas (Tsumeb, Grootfontein, Otavi and Outjo) and the surrounding Karstveld, in particular regarding the towns' use of groundwater and production of pollution.

5.5.3 Criteria for prioritisation of ecosystem services

5.5.3.1 Current and future expected impacts on the flow of the service

Livestock production and groundwater are facing threats to their flows but the exploitation of other provisioning services is generally expected to continue growing. The services relating to soil formation and composition and groundwater recharge are also under increasing pressure.

5.5.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

Abstraction of groundwater in the Karstveld may increase to meet the shortfall in supply to towns such as Windhoek. This will represent overexploitation as abstraction will exceed recharge rates, and is unsustainable in the medium to longer term.

Expansion of urban areas and increasing industrialisation

There are limited threats from industrialisation in this ecosystem zone.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the ecosystem zone to be used for agriculture, as well as the rate of groundwater recharge.

Rapid expansion of mining and prospecting

There are limited threats from the rapid expansion of mining and prospecting in this ecosystem zone.

Unsustainable land management practices

Overgrazing could be having significant impacts in the zone, resulting in land degradation and contributing to bush encroachment, reducing the rate of groundwater recharge, as well as affecting some cultural services.

Uncontrolled bush fires

Uncontrolled bush fires are not thought to be a major threat in this ecosystem zone.

Alien invasive species

There are no significant threats from alien invasive species in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

Poaching is a growing pressure, although is not yet at a high enough level to threaten the delivery of ecosystem services. It could in the future impact on recreational tourism and some other cultural services, however.

Human-wildlife conflict

Human-wildlife conflict in the zone is fairly limited; there may be some offtake of livestock by predators but these are often tolerated as a result of their tourism value.

5.5.3.3 Economic importance (current and potential)

Recreational tourism facilitated by Etosha and the surrounding reserves is of significant economic importance to Namibia. The commercial production of livestock and crops and the provision of water for industry and mining are also economically important to Namibia.

5.5.3.4 Affected population (size and socio-economic characteristics)

As most of the rural population are farmers or employees of private reserves, the production of livestock, crops and recreational tourism are of significant importance to these individuals. The recreational tourism generated by Etosha and the surrounding farms also affects a much wider population given both its contribution to the national economy and that it attracts tourists from all over the world. The Hei/Om are likely to be some of the poorest in the zone, so services relating to their culture and way of life could also be prioritised by this criterion.

5.5.3.5 Availability of data

The services with the greatest availability of data are likely to be marketed provisioning services (such as livestock and crops), as these transactions are registered and consequently the estimation of their flows is relatively simple. Tourism to Etosha is measured and recorded, and tourist numbers to private farms in the ecosystem zone should also be available. The Etosha Ecological Institute produces research around a number of ecosystem processes and services principally within the Etosha National Park, but which may also apply to some extent to the wider ecosystem zone. The numbers of wildlife within the park are estimated by game counts on an annual basis, and estimates of wildlife in private reserves should also be available.

5.5.4 References

Heyns, P. 2008. Application of a basin management approach to groundwater utilization in the Otavi Mountain Land, Namibia. Physics and Chemistry of the Earth, Parts A/B/C, 33(8–13): 913–918.

Mendelsohn, J.M. 2006. Farming systems in Namibia. RAISON, Windhoek.

Mendelsohn JM, Robertson T and A Jarvis. 2013. A profile and atlas of the Cuvelai-Etosha Basin. RAISON and Gondwana Collection, Windhoek.

Miller RM, Pickford M and Senut B. 2010. The geology, palaeontology and evolution of the Etosha Pan, Namibia: implications for terminal Kalahari deposition. South African Journal of Geology 113: 307- 334.

Oshikoto regional poverty profile: based on village-level participatory poverty assessment in Omusati Region, Namibia, December 2005-March 2006. Namibia, National Planning Commission.

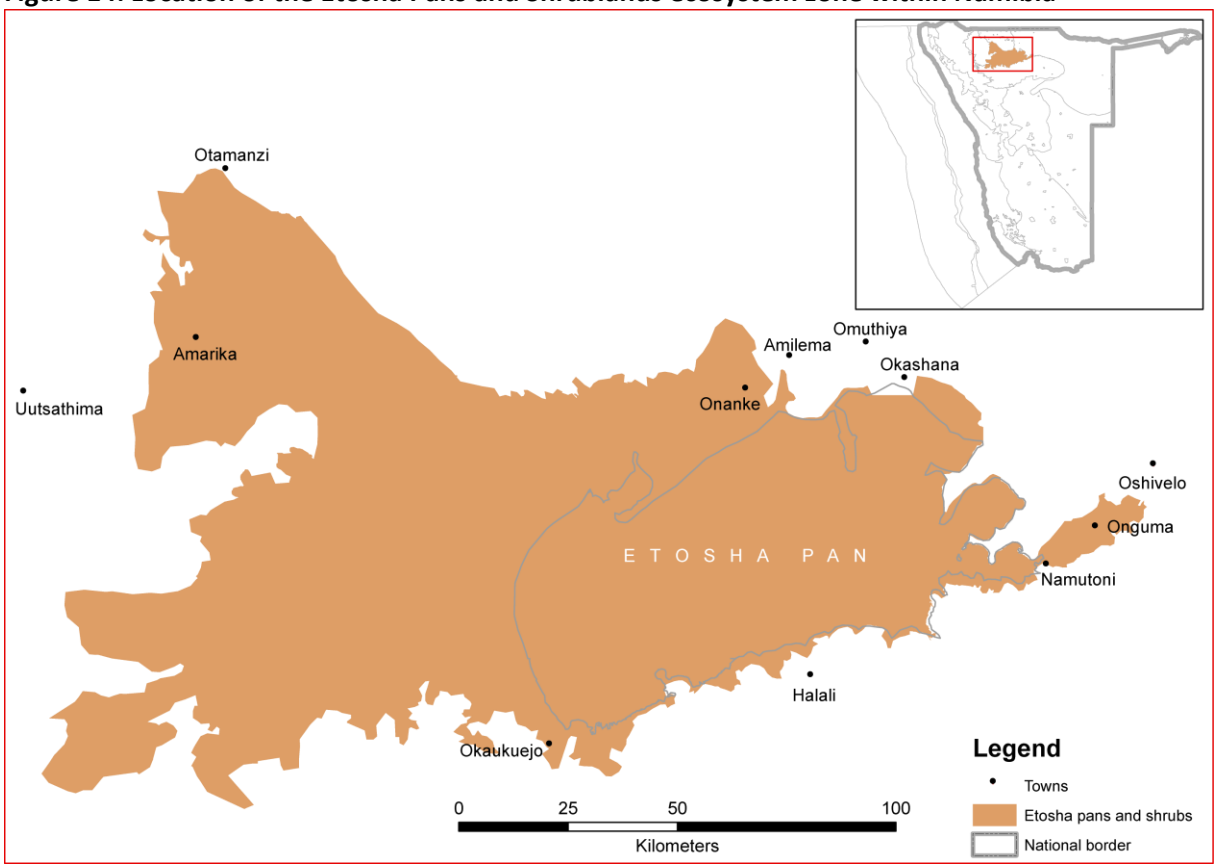
5.6 Etosha Pans and Shrublands

5.6.1 Description and assessment of ecosystem zone

5.6.1.1 Main attributes and ecological processes

The Etosha Pans and Shrublands ecosystem zone covers approximately 15,400 km^2 in north-central Namibia, and is presented in Figure 14. It is characterised by high levels of salinity; either as almost pure salt covering the surface of pans, or in very saline soils to which only certain plant species are adapted. The salinity is a consequence of salts being left behind in sediments by the evaporation of water that accumulated here over very long periods. Most of the water flowed seasonally down the Cuvelai Drainage system and could flow no further than this zone because of the raised southern margins of the Cuvelai Basin.

Figure 14: Location of the Etosha Pans and Shrublands ecosystem zone within Namibia



Etosha is by far the biggest and best known pan, but there are about 60 other significant pans, some of which are of a substantial size (e.g. Adamax, Natkanoka, Pan Point and Onanzi). Most of the pans are completely dry for much of the time, and only Etosha continues to receive water regularly down the Ekuma River from the Cuvelai; the other pans are occasionally flooded after heavy local rainfall. All the pans are slightly lower than the surrounding landscape, which is extremely flat. Their lower elevations are a consequence of frequent scouring by strong winds. The winds are strongest in winter when fine sediments swept off the pans can be blown as far as the Atlantic coast.

There is little or no vegetation on most of the pans. Shrub- and grassland dominate the vegetation on the saline salts elsewhere, while dwarf mopane grow on non-saline sandy flats with shallow

calcrete hardpan that cover much of the north-western area. Substantial numbers of livestock are supported by this vegetation north of Etosha National Park, while grass and shrublands west of Etosha Pan are favoured grazing areas for thousands of Burchell's zebra, springbok and blue wildebeest within the Park. The animals move there following good rains and remain there for much of the summer. Etosha Pan is also home to large numbers of big mammals such as elephant, black and white rhino, giraffe, lion, leopard and cheetah.

Etosha Pan has been declared as a RAMSAR site in recognition of its international importance as a wetland for water birds. Tens, sometimes hundreds of thousands of flamingos move to the Pan when it is flooded and may breed there. White Pelicans may also breed there when fish are abundant in the Ekuma River and Omadhiya Lakes just to the north of the Zone. With the exception of surface water that accumulates locally after rain, and water in several artesian springs, there are no other natural sources of water. The zone is also home to at least one range-restricted endemic reptile.

5.6.1.2 Human activity and population

Most of the zone lies within Etosha National Park. There are no significant towns in the zone, and most residents in the Park are staff who run conservation activities and the four entrance gates and multiple lodges and camps for visitors. The entire area of this zone to the north of Etosha National Park is communal land, and there are few permanent residents there. Part of the zone falls within Sheya Shuushona, King Nehale and Lipumbu ya Tshilongo conservancies.

The estimated population for the zone was 9,000 in 2011. This represents a slight reduction (2%) from the estimated population of 9,200 in 2001, and corresponds to a population density of approximately 0.58 people per km^2.

5.6.1.3 Pressures and drivers of change

Table 28: Broad drivers of change and ecosystem-specific pressures in the Etosha Pans and Shrublands ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Overgrazing; expropriation of communal land into private land
Exploitation	Increases in livestock numbers
Pollution	No relevant pressures in this zone
Invasive species	No relevant pressures in this zone
Climate change	Potential to increase rate of bush encroachment
Illegal use	Poaching, particularly of rhino, within Etosha

Table 28 relates the six broad categories of drivers of change to specific pressures within the Etosha Pans and Shrublands ecosystem zone. As much of the zone lies within Etosha National Park, there is less scope for direct human activity to impact on its functioning.

On communal land in the north of the zone there have been large increases in cattle numbers and, alongside the expropriation of communal land into effective private land, this has resulted in overgrazing and consequent reductions in available pasture. As in other zones (such as the Kalahari Woodlands and the Highland Acacia Savanna) this could well lead to a reduction in fire and increased

rates of bush encroachment. However, this is not thought to be as severe a pressure as in some of the other zones.

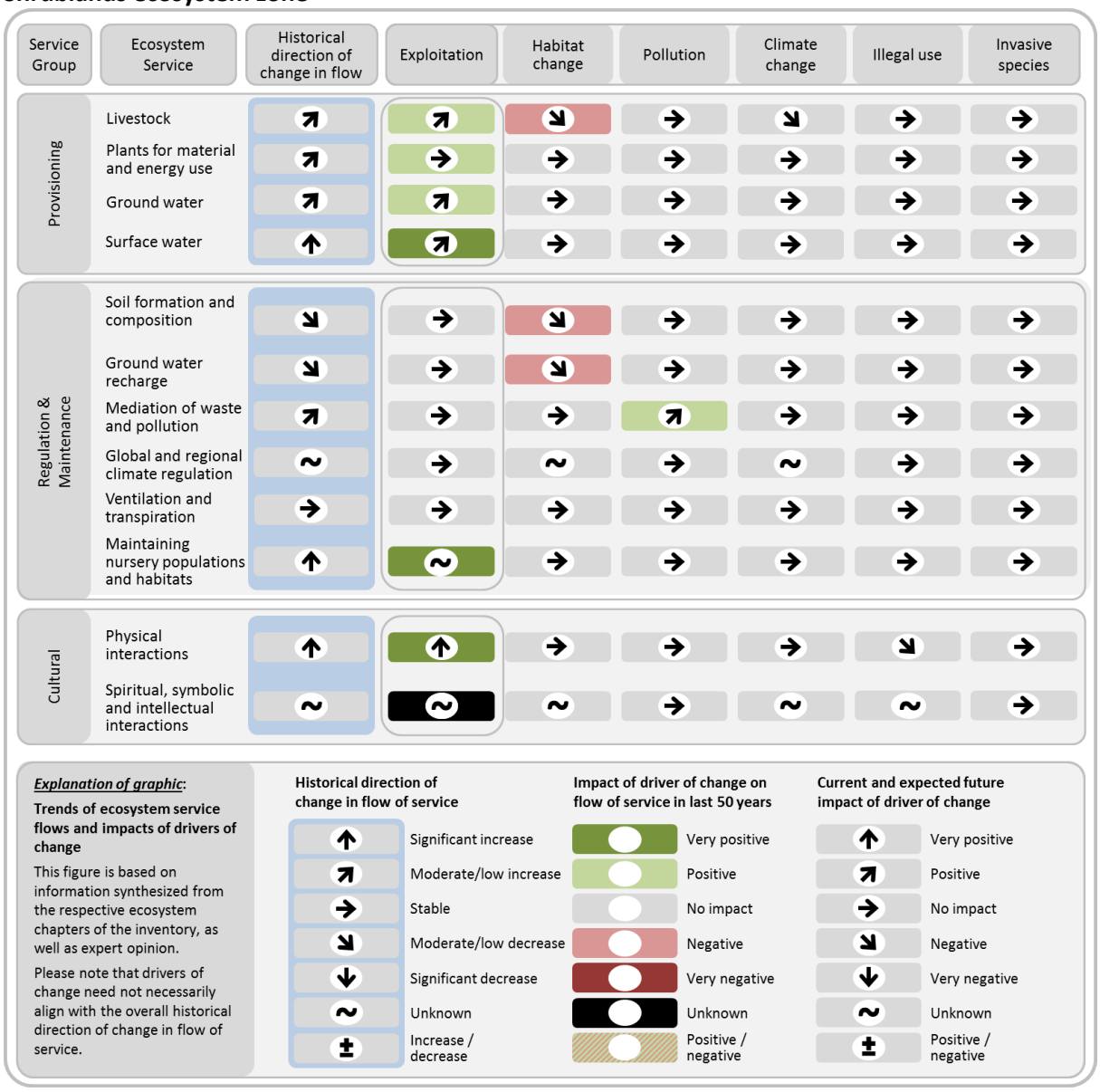
Within Etosha, an escalating threat has been the poaching of wildlife, in particular, rhino. Between October 2014 and April 7th 2015, 11 rhino had been confirmed poached within Etosha, and a total of 24 rhino were poached in Namibia in 2014. This compares to zero incidents between 2006 and 2008, and just one incident as recently as 2012.

The effects of climate change may be realised through increased rates of bush encroachment. There are no relevant pressures relating to pollution or invasive species.

5.6.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Etosha Pans and Shrublands ecosystem zone. Figure 15 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 15: Overview of flows of services and impacts from drivers of change in the Etosha Pans and Shrublands ecosystem zone



5.6.2.1 Provisioning

Table 29 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Etosha Pans and Shrublands (and which are comparable to those classes specified in Figure 15). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 29: Overview of provisioning services in the Etosha Pans and Shrublands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Reared animals and their outputs	Meat and dairy from livestock (cattle)	Regional	Consumptive use
Reared animals and their outputs	Livestock as capital (cattle)	National	Option
Surface water for non-drinking purposes	Water for wildlife at waterholes (natural and man-made)	Local	Consumptive use
Groundwater for non-drinking purposes	Water for livestock	Local	Consumptive use
Plant-based energy	Wood fuel	Local	Consumptive use

Description

As much of the zone falls within Etosha National Park, there is limited scope for provisioning services in the ecosystem zone; indeed the only provisioning service occurring within the Park's boundaries is the provision of water for wildlife at waterholes, which are both natural and man-made. To the north of the Park is communal land, on which cattle is both farmed and kept, water is pumped from aquifers for livestock, and wood is harvested as a source of fuel for heating and cooking.

Affected population

Cattle farming and keeping is relevant to the national population because many owners live outside of the zone. The other provisioning services are all relevant to populations primarily at a local level, as they are used in the vicinity of their harvesting or abstraction.

Change in flow over past 50 years

Cattle-keeping and consequently the abstraction of groundwater for livestock have increased fairly rapidly reflecting increases in cattle populations. The provisioning of water for wildlife has likely increased slightly in recent decades as a result of the growth in private nature reserves and tourism enterprises, although water provisioning over this period in Etosha itself is thought to be fairly stable as few new boreholes have been added since the 1970s, and some in the western parts of the park have been closed as it became apparent they facilitated overgrazing.

Pressures and expected impacts on flow of service

The exploitation of these provisioning services is generally expected to continue rising. Increases in livestock are likely to be focused on cattle keeping as opposed to cattle farming, which will also drive continued exploitation of groundwater for livestock. The growth in the provision of water for wildlife is likely to continue at broadly the same rate, as there will likely be further tourism developments focused on wildlife viewing.

Cattle keeping and farming may come under pressure from habitat change as a result of overgrazing and bush encroachment.

5.6.2.2 Regulation and maintenance

Table 30 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Etosha Pans and Shrublands.

Table 30: Overview of regulation and maintenance services in the Etosha Pans and Shrublands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect use
Ventilation and transpiration	Vegetation cover enabling air ventilation	Regional	Indirect use
Maintaining nursery populations and habitats	Etosha as key conservation area	International	Indirect use
Weathering processes	Decomposition/mineralisation of dead organic material, nitrification	Regional	Indirect use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	International	Indirect use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances is generated largely at the ecosystem level by the absorption of pollutants and the dilution of gases into the atmosphere. The mediation of flows relates to both liquids, with regard to groundwater recharge, and gases, through vegetation enabling air ventilation.

Soil formation and composition, (through both the decomposition/mineralisation of dead organic material and nitrification, as well as the maintenance of the fertility of soils, nutrient storage and their soil structure) and atmospheric composition and climate regulation (through carbon sequestration and the maintenance of regional precipitation/temperature patterns) are key services. Etosha (the majority of which falls within the zone) represents a major conservation area in Namibia, supporting many species, including white and black rhino, elephant, lion, leopard and cheetah (maintaining nursery populations and habitats).

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of liquid and gaseous flows. The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level. Etosha as a key conservation area is relevant internationally. Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

The absorption and dilution of pollutants in the ecosystem zone is thought to have increased as a result of slightly increased pollution from higher populations and more human activity, although this is generally likely to be of limited importance. Increased coverage of bush in the zone is estimated to have reduced the rate of groundwater recharge, particularly in the northern communal areas.

Overgrazing has resulted in a reduction in the flow of the soil formation and composition processes, but this is thought to be less significant than in some of the neighbouring ecosystem zones. The overall changes in carbon sequestration (due to potentially opposing impacts of loss of rangeland and increased bush) and micro and regional climate regulation are unknown, although they are thought to be generally insignificant. There is likely limited change in the flow of air ventilation. The importance of Etosha as a conservation area has increased significantly in recent decades as a result of its increased use for this purpose.

Pressures and expected impacts on flow of service

The absorption and dilution of pollutants is expected to continue increasing at a similar rate as human activity in the ecosystem zone continues to grow, although it is still likely to be a relatively insignificant service. The rate of groundwater recharge is likely to continue to decline as a result of bush encroachment, but this is unlikely to be significant enough to affect abstraction rates. The effect on groundwater recharge could be compounded by climate change inducing further growth of woody biomass.

The negative effects from habitat change on soil formation and composition are also likely to continue, although at relatively slow rates, as a result of overgrazing and bush encroachment particularly to the north of Etosha. Climate change may also impact on these processes.

It is not certain how the service relating to Etosha as a conservation area will change. It is likely to face increasing pressure from poaching; 54 rhino were poached in Etosha in the first half of 2015, compared to 24 in the whole of Namibia in 2014, and zero incidents between 2006 and 2008.

There is uncertainty around the net impact on carbon sequestration, due to the offsetting effects from bush encroachment and habitat change that reduces available rangeland. Climate change could also reduce regional precipitation, resulting in more arid conditions, but again it is unclear how significantly rainfall will decrease and over what time period it will occur.

5.6.2.3 Cultural

Table 31 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Etosha Pans and Shrublands.

Table 31: Overview of cultural services in the Etosha Pans and Shrublands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Wildlife viewing, recreational tourism	International	Non-consumptive use
Scientific	Etosha (Etosha Ecological Institute)	International	Consumptive use
Educational	Etosha	National	Non-consumptive use; existence; bequest
Heritage, cultural	Livelihoods, way of life	National	Non-consumptive use; existence; bequest
Entertainment	Ex-situ viewing of wildlife - Etosha	International	Non-consumptive use
Aesthetic	Representations of wildlife viewing in Namibia	International	Non-consumptive use
Symbolic	Etosha as symbolic of Namibia	International	Non-consumptive use
Existence	Relating to wildlife; livelihoods, way of life	International	Existence
Bequest	Relating to wildlife; livelihoods, way of life	International	Bequest

Description

Given that the majority of the zone (85%) lies within Etosha National Park, recreational tourism and in particular wildlife viewing is a very significant cultural service in the Etosha Pans and Shrublands. Etosha also supports a great deal of scientific research and educational activities, while also being symbolic of Namibia; it also contributes a great deal to the ex-situ viewing of wildlife and aesthetic services of representations of wildlife viewing in Namibia. Wildlife in Etosha has significant economic value to Namibia.

The communal lands to the north of Etosha may generate cultural and heritage services relating to the livelihoods and the way of life they support. Existence and bequest services may also be held relating to these services, as well as to the wildlife in the zone. Little recreational hunting takes place within the zone (as it is not permitted in Etosha National Park).

Affected population

Tourists to the zone are primarily international visitors; the scientific services and the existence and bequest services relating to wildlife are also relevant to international populations. The other services are all relevant to individuals living across Namibia.

Change in flow over past 50 years

Recreational tourism in Etosha has increased significantly in recent years. This has been driven by the opening up of Namibia and the development of tourism facilities in Etosha. Scientific and education services, the ex-situ viewing of wildlife, and aesthetic and symbolic services are also thought to have increased substantially in recent decades. The flows of other cultural services in the zone are not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone. A pressure to the service could be poaching, but it is not currently at a level where it is likely to affect tourism. The effects of pressures on other cultural services in the zone are generally poorly understood.

5.6.2.4 Interactions between ecosystem services

Predators and large mammals can escape from Etosha leading to human-wildlife conflict in the communal areas to the north, primarily representing a threat to livestock. In turn, livestock farmers or keepers may take measures to protect their assets, which can represent a pressure on the wildlife.

Overgrazing in the northern communal areas, particularly as a result of increased cattle keeping, is leading to land degradation and this is likely to continue; this also puts pressure on available land for wildlife. The farming and keeping of livestock is also likely heavily linked with cultural services relating to ways of life.

5.6.3 Criteria for prioritisation of ecosystem services

5.6.3.1 Current and future expected impacts on the flow of the service

There may be increasing threats to the production of beef as a result of land degradation, but this is not a particularly significant service in the zone. Overgrazing in areas is also likely negatively impacting soil formation and composition services.

5.6.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

There are limited threats from unsustainable water use in this ecosystem zone (the abstraction of groundwater is not thought to represent overexploitation).

Expansion of urban areas and increasing industrialisation

There are limited threats from industrialisation in this ecosystem zone.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the ecosystem zone to be used for agriculture, as well as impacting on Etosha.

Rapid expansion of mining and prospecting

There are no significant threats from the rapid expansion of mining and prospecting in this ecosystem zone.

Unsustainable land management practices

Overgrazing could be having significant impacts in the zone, resulting in land degradation in the northern communal areas.

Uncontrolled bush fires

Uncontrolled bush fires have destroyed habitat and killed animals in the zone in the past; this could impact on tourism and its status as a key conservation area.

Alien invasive species

There are no significant threats from alien invasive species in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

Poaching is a growing pressure, although is not yet at a significant enough level to threaten the delivery of ecosystem services. It could in the future impact on recreational tourism and some other cultural services, however.

Human-wildlife conflict

Human-wildlife conflict in the zone may be an issue to the north of Etosha in the communal lands. There is less tolerance of it than in other ecosystem zones surrounding Etosha as there is little benefit in allowing wildlife or predators into the communal areas due to very limited tourism.

5.6.3.3 Economic importance (current and potential)

Recreational tourism facilitated by Etosha is of significant economic importance to Namibia.

5.6.3.4 Affected population (size and socio-economic characteristics)

The recreational tourism generated by Etosha affects the international population given both its contribution to the national economy and its attraction for tourists from around the world.

5.6.3.5 Availability of data

Tourism to Etosha is measured and recorded, and tourist numbers to private farms in the ecosystem zone should also be available. The Etosha Ecological Institute produces research around a number of ecosystem processes and services principally within the Etosha National Park, but which may also apply to some extent to the wider ecosystem zone. The numbers of wildlife within the park are estimated by game counts on an annual basis.

5.6.4 References

Berry HH. 1997. Historical review of the Etosha region and its subsequent administration as a national park. Madoqua 20: 3-12.

Beugler-Bell, H and MW Buch, 1997. Soils and soil erosion in the Etosha National Park. Madoqua 20: 91-104.

Du Plessis, W. 1999. Linear regression relationships between NDVI, vegetation and rainfall in Etosha National Park, Namibia. Journal of arid environments, 42:235–260.

Enviro Dynamics. 2013. Environmental Impact Assessment for the proposed Otjivalunda salt mining and soap production facility. Windhoek.

Kemp, L., Mendelsohn, J. and Jones, B. 2009. The Sheya Uushona Conservancy. Published in 2009 by the Namibia Nature Foundation on behalf of the Natural Resources Working Group of NACSO, with financial support from WWF Norway

Mendelsohn JM, Robertson T and A Jarvis. 2013. A profile and atlas of the Cuvelai-Etosha Basin. RAISON and Gondwana Collection, Windhoek.

Miller RM, Pickford M and Senut B. 2010. The geology, palaeontology and evolution of the Etosha Pan, Namibia: implications for terminal Kalahari deposition. South African Journal of Geology 113: 307- 334.

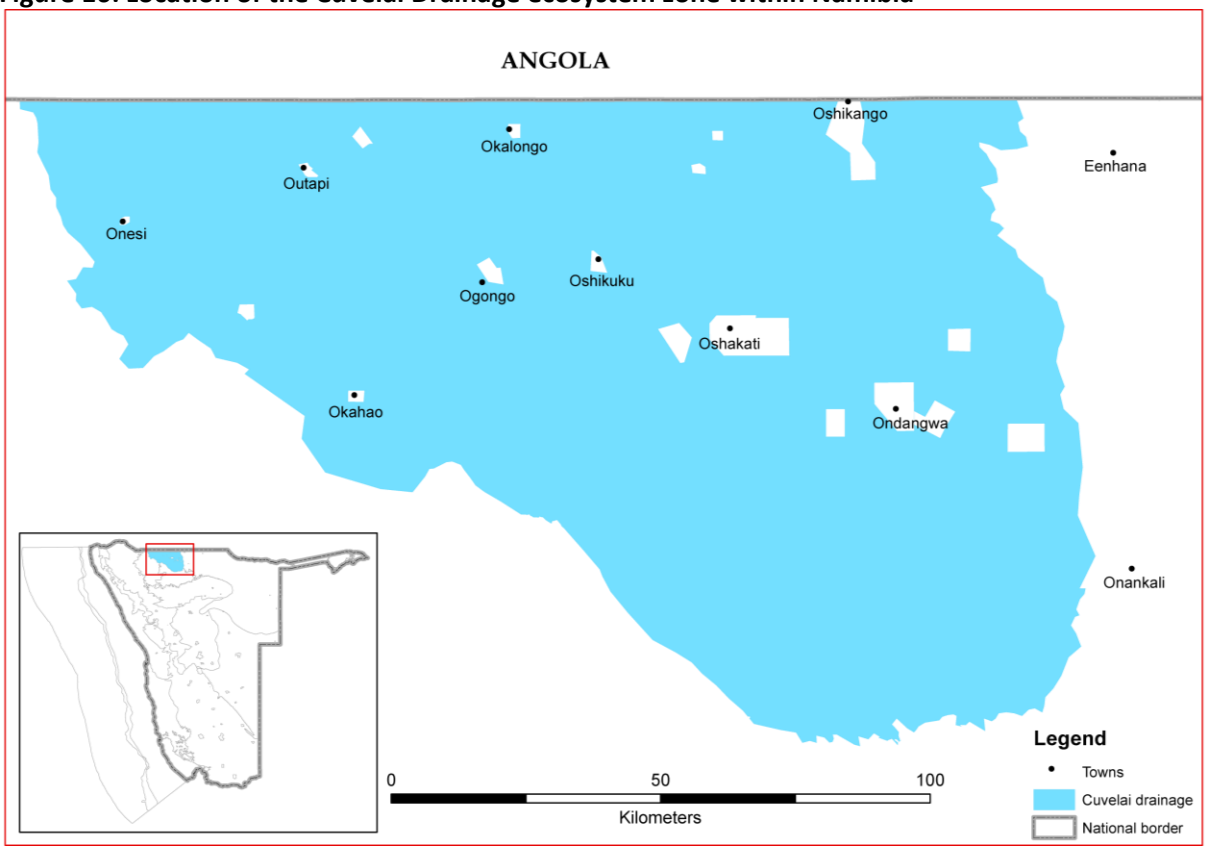
5.7 Cuvelai Drainage

5.7.1 Description and assessment of ecosystem zone

5.7.1.1 Main attributes and ecological processes

The Cuvelai Drainage ecosystem zone is a unique mosaic of hundreds of interconnected ephemeral channels (*iishana*) and sandy uplands (*omitunda*) which form part of the Cuvelai Basin. About half the Basin is in Angola from where surface water in the *iishana* flows into the Namibian southern half. The *iishana* converge to form the Omadhiya Lakes from where water may flow further along the Ekuma River into Etosha Pan. Gradients across the whole Basin are extremely shallow. Surface flows are thus slow, seldom exceeding 10 kilometres per day. The Cuvelai is also part of the much larger expanse of sediments that makes up the Kalahari Basin. It covers approximately 14,000 square kilometres (Figure 16).

Figure 16: Location of the Cuvelai Drainage ecosystem zone within Namibia



Much of the surface water flowing from north to south does not reach the Omadhiya Lakes, particularly during seasons with average or below rainfall; the water either seeps away or evaporates. Rates of evaporation are greatest in the southern areas of the Zone where the *iishana* are generally broader and thus shallower than to the north. In addition to flows from Angola, substantial proportions of water in the *iishana* are from local rainfall, particularly after soils have become saturated. Local rain also fills thousands of small pans and ponds (called *eendobe*).

The broader and shallower *iishana* to the south of the zone have led to the formation of saline soils and groundwater which make much of it unsuitable for arable agriculture and human habitation. By

comparison, the soils in the northern part of the zone are comparatively fertile, where sediments of alluvial and aeolian origin have been mixed into cambiosol and calciosol soils, and groundwater is not saline. Grasses predominate in the *iishana* channels, particularly those with bases of saline clays, while mopane, jackal berry and palms are generally the only trees and are found on slightly higher ground that is flooded less frequently. On even higher ground with sandier soils, wild figs, marula, bird plums and trees characteristic of the Northern Kalahari Woodland are present.

5.7.1.2 Human activity and population

There are four towns with a population of around 20,000 residents or more: Oshakati (37,000), Ondangwa (23,000), Ongwediva (20,000) and Helao Nafidi (19,000). Ondangwa and Ongwediva are growing particularly rapidly, the former increasing its population by almost 110% since 2001 and the latter by almost 90%. By comparison, the population of Oshakati has grown less rapidly, by about 30% since 2001. Helao Nafidi was established in 2004 as an amalgamation of a number of settlements, including Oshikango. There are a number of smaller towns in the zone, including Outapi, Oshikuku and Okahao. All the towns are part of the Urban ecosystem zone (see Section 5.16.4).

The rural population of the Cuvelai Drainage ecosystem zone was estimated at 488,000 in 2011, a reduction of approximately 4% its level in 2001 (510,000). This is the most densely populated rural area in Namibia by some margin, at 34 people per km^2. The Cuvelai Drainage has been occupied by relatively large numbers of people for at least 500 years and much of the indigenous landscape has been deforested, the trees being used for fencing and houses and other areas being cultivated. Forage is heavily exploited by large numbers of cattle, goats and donkeys. Rural homes are spread out rather evenly, most being between several hundred metres and one to two kilometres from their neighbours. Each home is surrounded by fields and areas of uncultivated land over which its residents have exclusive user rights. This is all communal land.

There are no protected areas in the zone and only small parts of conservancies fall within it. It is difficult to estimate socio-economic characteristics for the zone because it encompasses parts of the Ohangwena, Omusati, Oshana and Oshikoto regions. The majority falls within Omusati and Oshana, and these generally have lower incidences of poverty than elsewhere in Namibia (third and fourth lowest, respectively), and average rural consumption per capita is above the national average.

5.7.1.3 Pressures and drivers of change

Table 32: Broad drivers of change and ecosystem-specific pressures in the Cuvelai Drainage ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Overgrazing; clearing of land through deforestation and for residents and crops; inappropriate ploughing/tillage practices
Exploitation	Abstraction of ground and surface water; harvesting of wood; increases in livestock numbers
Pollution	Rapidly increasing urban population causes increasing pollution in the rural Cuvelai Drainage
Invasive species	No relevant pressures identified in this zone
Climate change	Few relevant pressures identified in this zone
Illegal use	No relevant pressures identified in this zone

Table 32 relates the six broad categories of drivers of change to specific pressures within the Cuvelai Drainage ecosystem zone. As in many other ecosystem zones across Namibia, overgrazing is a particular pressure, reducing available pasture and forage and contributing to soil erosion. The clearing of land for crops and through deforestation, as well as inappropriate ploughing/tillage practices probably contribute to erosion of soil which may fill *iishana* and increase the extent of flooding.

Deforestation is particularly visible on the Namibian side of the Cuvelai as a result of the more dense population than in Angola. The denser population largely reflects Angolan migration to Namibia, particularly as Angolans have been attracted by economic opportunities and social services in Namibia, as well as escaping harsh conditions, for example taxation in the 1930s, the liberation war in the 1960s and early 1970s, and civil war in the 1980s and 1990s. Deforestation and land clearing have largely stopped, however, as a result of significant rates of rural-urban migration. Furthermore, rural homes are increasingly built and fenced with bricks and wire, and this has reduced harvesting of wood for building and fencing. It is possible that woodlands are recovering in certain areas of the Cuvelai.

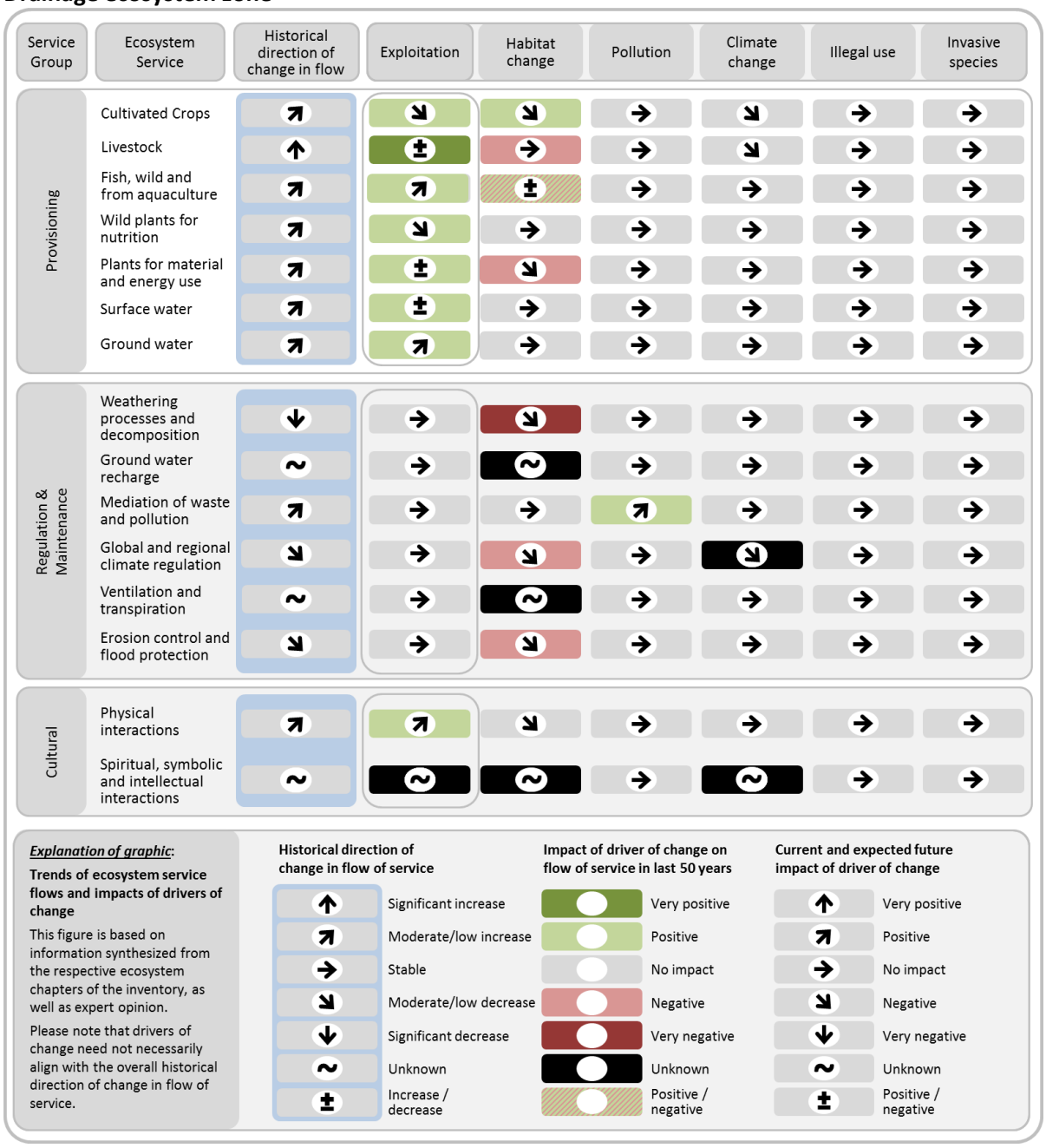
Livestock numbers have increased rapidly in the Cuvelai Drainage ecosystem zone. The owners of most cattle are primarily wage earners that live in towns rather than communal lands. The abstraction of groundwater is occurring through shallow, hand-dug wells, and surface water is pumped from the Kunene River at Calueque in Angola. Neither form of abstraction is occurring at a significant enough rate to impact on surface or groundwater.

If climate change brings about hotter temperatures and greater evaporation rates, this would affect crop growth. Solid waste is increasingly spread from local towns into surrounding rural areas, especially when floodwaters flow through towns and carry waste downstream. Substantial volumes of waste wash into Namibia from towns in the Angolan Cuvelai.

5.7.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Cuvelai Drainage ecosystem zone. Figure 17 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 17: Overview of flows of services and impacts from drivers of change in the Cuvelai Drainage ecosystem zone



5.7.2.1 Provisioning

Table 33 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Cuvelai Drainage (and which are comparable to those classes specified in Figure 17).

It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 33: Overview of provisioning services in the Cuvelai Drainage ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Cultivated crops	Millet, sorghum, vegetables	National	Consumptive use
Reared animals and their outputs	Meat and dairy from livestock (cattle, goats)	Regional	Consumptive use
Reared animals and their outputs	Cattle as capital	National	Option
Wild plants, algae and their outputs	Indigenous fruits (marula, bird plum, jackal berry, mangetti)	Regional	Consumptive use
Wild animals and their outputs	Fish	Regional	Consumptive use
Wild animals and their outputs	Small mammals and birds	Local	Consumptive use
Animals from in-situ aquaculture	Fish farm at Epalela	Regional	Consumptive use
Surface water for drinking	Drinking water pumped from the Kunene	Regional	Consumptive use
Surface water for drinking	Drinking water from *eendobe*	Local	Consumptive use
Groundwater for drinking	Drinking water from aquifers	Local	Consumptive use
Fibres and other materials from plants, algae and animals for direct use or processing	Wood for fencing and construction of houses, bark for rope and baskets; skins from livestock	Local	Consumptive use
Fibres and other materials from plants, algae and animals for direct use or processing	INPs for processing e.g. marula oil	International	Consumptive use
Surface water for non-drinking purposes	Water for domestic urban use, industrial and commercial use and irrigation pumped from the Kunene	Regional	Consumptive use
Surface water for non-drinking purposes	Water from eendobe for livestock and domestic rural use	Local	Consumptive use
Groundwater for non-drinking purposes	Water for domestic rural use and livestock from aquifers	Local	Consumptive use
Plant-based resources	Fuel wood	Local	Consumptive use
Animal-based energy	Donkeys for transport	Local	Consumptive use

Description

The comparatively high population density in the Cuvelai Drainage ecosystem zone gives rise to a number of provisioning services. The production of livestock for meat and dairy products (in particularly cattle and goats) and cultivated crops (such as pearl millet, vegetables and sorghum) are important sources of nutrition; a family produces approximately 1,000 kg of millet a year on average, but production is extremely variable as a result of varying rainfall, field sizes and fertility, and the availability of labour.

To a lesser extent, indigenous fruits such as marula, bird plum, jackal berry and mangetti are also harvested for food, as well as fish and small mammals and birds. There is also a fish farm at Epalela. Significant numbers of cattle are kept as a form of capital.

Drinking water is obtained from three main sources. Surface water is pumped from the Kunene at Calueque in Angola and then distributed from purification plants at Olushandja, Outapi, Ogongo and Oshakati; the Olushandja Dam also holds water in reserve to last several months in the event of the pumped supply being disrupted. Surface water is also harvested from shallow wells for drinking, but this is of much lesser importance. A final source of drinking water is groundwater pumped from aquifers.

These sources are also used to provide water for non-drinking purposes. Water from the Kunene is the main source used for domestic urban use, industrial, commercial and irrigation. Water from *eendobe* is primarily used for livestock, while water for domestic rural use is more likely to come from groundwater pumped from aquifers.

Wood is harvested in the zone to provide fuel and products for fencing and the construction of houses, while bark is used for rope and baskets. INPs and fruits are also harvested in the zone for processing; for example marula is used to produce oil for cooking. In addition to nutritional purposes, livestock are utilised for their skins. Donkeys are used to transport people and goods between rural areas.

Affected population

Most of the services relating to the production of food are relevant to regional populations, although cultivated crops are produced commercially on a small scale in some places, and are therefore relevant across the country. The harvesting of small mammals and birds for food benefits local populations as it is on an informal basis.

Surface water pumped from the Kunene for both drinking and non-drinking purposes is important to regional populations. Sources of groundwater generally benefit local people. The harvesting of wood for fuel and construction, and the use of donkeys for transportation are also generally relevant to local populations. Marula oil is exported internationally.

Change in flow over past 50 years

Almost all provisioning services have demonstrated increases in recent decades, largely reflecting increased exploitation as a result of growing populations in the zone. Those services increasing the most rapidly are generally related to the pumping of water from the Kunene for drinking, domestic, industrial, commercial and irrigation uses. Services relating to the production of food, provision of materials for local construction and the provision of water for livestock have also increased over the past 50 years. However, more recently, construction materials harvested from woodlands have probably declined as people have turned to bricks and wire instead. The hunting of small mammals and birds has declined as incomes have increased and other sources of food have become more widely available. Crop production may also have declined slightly for the same reason.

Pressures and expected impacts on flow of service

There are expected to be significant changes in the patterns of the exploitation of provisioning services relating to food. Meat and dairy from livestock is generally not expected to grow as rural populations decline and carrying capacities have been exceeded; although there may still be some increases in goat farming. Cattle keeping is expected to keep expanding. The exploitation of fish is likely to continue to rise, while consumption of indigenous fruits may decline as people switch to other sources of food. The hunting of small mammals and birds is likely to be insignificant.

Habitat change through land degradation has generally had a negative impact on the capacity of the ecosystem zone to provide these services, particularly with regard to the production of beef and dairy from cattle (although there are likely to be lesser impacts on cattle keeping and goat farming). The clearing of land for crops had previously increased the scope for arable agriculture, but the loss of nutrients in fields that have been used repeatedly with little replenishment is reducing yields. The harvesting of wild fish may be restricted by increasing siltation. Climate change may also exacerbate negative pressures on livestock and crop farming.

Water pumped from the Kunene is expected to continue to rise significantly, both for drinking and non-drinking purposes. This is being driven by rapidly growing urban populations within the zone. Water pumped from aquifers is also expected to continue increasing, particularly with regard to its use for livestock, but at a slower rate than water from the Kunene. Water harvested from shallow wells, particularly for drinking, is expected to decline as alternative sources are easier to find.

Declines in rural populations and the use of alternative building materials are expected to reduce exploitation of wood for building materials; its use is also limited as a result of previous clearing of woodland. The use of livestock for skins, fuel wood and donkeys for transport is expected to decline because of shrinking rural populations and substitute materials or options being available. The harvesting of INPs for processing is likely to continue growing, albeit at a slightly reduced rate.

5.7.2.2 Regulation and maintenance

Table 34 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Cuvelai Drainage.

Table 34: Overview of regulation and maintenance services in the Cuvelai Drainage ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect use
Flood protection	Protection from flood waters	Regional	Indirect use
Ventilation and transpiration	Vegetation enabling air ventilation	Regional	Indirect use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure	Local	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances is generated largely at the ecosystem level by the absorption of pollutants and the dilution of gases into the atmosphere. The mediation of flows relates to both liquids, with regard to groundwater recharge and flood protection, and gases, through vegetation enabling air ventilation. Relevant services in the maintenance of physical, chemical and biological conditions division relate to soil composition and formation (the maintenance of the fertility of soils, nutrient storage and soil structure) and atmospheric composition of climate regulation (through carbon sequestration and the maintenance of regional precipitation/temperature patterns).

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of liquid and gaseous flows. The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level. Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

The absorption and dilution of pollutants in the ecosystem zone is thought to have increased as a result of increased pollution from higher populations and more human activity, and although this increase has been perhaps greater than in many other ecosystem zones, it is generally likely to be of limited importance. The extent of flood waters in the zone is likely to have increased as a result of overgrazing and soil erosion; the effect (if any) on the rate of groundwater recharge from these impacts is not well understood.

Overgrazing, intense cropping and poor ploughing practices have resulted in a significant reduction in the services related to soil formation and composition. The historical change in carbon sequestration is thought to be negative because of the clearing of woodland. The effects on air ventilation and micro and regional climate regulation are unknown.

Pressures and expected impacts on flow of service

The absorption and dilution of pollutants is expected to continue increasing at a similar rate as human activity in the ecosystem zone expands; further research is needed to determine the ongoing ability to of the ecosystem zone to mediate these pressures. The negative effect on flood protection is likely to continue as overgrazing and soil erosion continues, and the future changes in the rate of groundwater recharge are not well understood.

The negative effects from habitat change on soil formation and composition are also likely to continue, although at a lesser rate as its condition has already deteriorated significantly. Carbon sequestration is also expected to continue declining as more rangelands are lost. Climate change could reduce regional precipitation, resulting in more arid conditions, but again it is unclear how significantly rainfall will decrease and over what time period it will occur.

5.7.2.3 Cultural

Table 35 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Cuvelai Drainage.

Table 35: Overview of cultural services in the Cuvelai Drainage ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Recreational tourism	International	Non-consumptive use
Heritage, cultural	Home to many Namibians, particularly Owambo people; Owamboland homeland; key area in independence struggle; livelihoods, way of life	National	Non-consumptive use; bequest; existence
Aesthetic	Representations of traditional Owambo culture/lifestyle	International	Non-consumptive use
Existence	Relating to Owambo culture etc.	National	Existence
Bequest	Relating to Owambo culture etc.	National	Bequest

Description

Little recreational tourism occurs in the Cuvelai. Perhaps the most significant cultural service in the zone relates to its representation of home for many Namibians, in particular Owambos, and the livelihoods and ways of life it supports. The Cuvelai was also a key area in the independence struggle. Existence and bequest services are likely to be derived relating to Owambo culture, ways of life and livelihoods. A less significant service relates to aesthetic representations of Owambo culture and life in Namibia.

Affected population

Tourists to the zone are primarily international visitors; the aesthetic services are also relevant to international populations. Existence and bequest services relating to culture and ways of life and the heritage and cultural services derived from the zone are relevant at the national level.

Change in flow over past 50 years

Recreational tourism has increased in recent years, but it is still not as significant in the Cuvelai as in neighbouring zones. The flow of other cultural services is generally not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone. Changes in flow of the other cultural services are not well understood.

5.7.2.4 Interactions between ecosystem services

Significant overgrazing in the Cuvelai Drainage ecosystem zone has led to land degradation and perhaps soil erosion, which in turn has reduced the carrying capacity of the area with regard to livestock. Soil erosion is also thought to have contributed to increases in flood waters in the zone.

5.7.3 Criteria for prioritisation of ecosystem services

5.7.3.1 Current and future expected impacts on the flow of the service

The most significant threats are to soil formation and composition services, and consequently the habitat they provide for livestock.

5.7.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

There are limited threats from unsustainable water use in this ecosystem zone. The current abstraction rate of groundwater is thought to be sustainable.

Expansion of urban areas and increasing industrialisation

Urban areas are growing rapidly in the ecosystem zone, and this is leading to increased levels of pollution. Further research is needed to understand the ongoing ability of the ecosystem zone to mediate the impacts of this pollution, and whether it is having any impacts on water provisioning. Conversely, as much of the urban expansion is as a result of rural-urban migration, pressures on

some rural services may decline, for example those associated with crop production, wood and water uses.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the ecosystem zone to be used for agriculture. Climate change may lead to more flooding and drought, both of which may affect large numbers of people, but evidence is lacking.

Rapid expansion of mining and prospecting

There are no significant threats from the rapid expansion of mining and prospecting in this ecosystem zone.

Unsustainable land management practices

Overgrazing, land clearing, habitat destruction, deforestation, crop production, and perhaps soil erosion have had significant impacts in the zone, leading to soil and land degradation.

Uncontrolled bush fires

Uncontrolled bush fires are not a threat in this ecosystem zone.

Alien invasive species

There are no significant threats from alien invasive species in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

There are no significant ongoing threats from illegal harvesting of wildlife, forest or plant products in this ecosystem zone. However for wildlife at least this reflects that human populations in the ecosystem zone reduced these populations significantly in the past.

Human-wildlife conflict

Human-wildlife conflict in the zone is limited.

5.7.3.3 Economic importance (current and potential)

The services of greatest economic importance are crop and meat production.

5.7.3.4 Affected population (size and socio-economic characteristics)

Cultural services in the zone relating to ways of life (for example cattle farming and keeping) and its significance as 'home' are also important to large numbers of individuals across Namibia.

5.7.3.5 Availability of data

The services with the greatest availability of data are likely to be provisioning services (such as livestock), as these resources are registered and consequently the estimation of their flows is relatively simple. It should also be possible to obtain data for the use of water in urban areas and piped water to rural areas.

5.7.4 References

Erkkilä, A. 2001. Living on the land: change in forest cover in north-central Namibia 1943-1996. Silva Carelica 37. University of Joensuu, Finland.

Groundwater for the North of Namibia. Summary Report of Activities of Phase I: Exploration of Ohangwena II Aquifer and Preliminary Isotope Study.

Hayes, P. 1992. A history of the Ovambo of Namibia c. 1880–1935. Unpublished PhD thesis, Cambridge University, United Kingdom.

Kangombe FN and Haarmeyer DH. 2010. Ogongo (S42). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Kangombe FN and Haarmeyer DH. 2010. Omano go Ndjamba (S43). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Keyler, S. 1995. Economics of the pearl millet subsector in Northern Namibia. A summary of baseline data. International Crops Research Institute for the Semi-Arid Tropics. Working Paper 95/03.

Kreike, E.H.P.M. 1995. The Ovambo agro-silvipastoral system: Traditional land use and indigenous natural resource management in northcentral Namibia. Forestry Publication No. 4. Directorate of Forestry, Ministry of Environment and Tourism, Republic of Namibia (Windhoek)

Marsh, A., Seely, M., 1992. Oshanas: Sustaining People, Environment and Development in Central Owambo, Namibia. Desert Research Foundation and SIDA,

Negumbo, H.M.T. 2004. Fuel wood consumption in Namibia: a case study on fuel wood consumption in Oshana Region. University of Wales, Bangor.

Siiskonen, H. 1990. Trade and socioeconomic change in Ovamboland, 1850–1906. Helsinki: Societas Historicas Fennica.

Soini, S. 1981. Agriculture in Northern Namibia, Ovambo and Kavango 1965–1970. J. Sci. Agricultural Soc. of Finland 53: 168–209.

Stern C and Lau B. 1990. Namibian water resources and their management, a preliminary history. Archeia 15. National Archives of Namibia.

van der Waal B. 2000. Fish resource management study of the Omadhiya Wetland Complex, Oshana Region. Report to Northern Namibia Environmental Project, Ministry of Environment and Tourism.

Williams, F.-N, 1994. Precolonial Communities of Southwestern Africa: A History of Owambo Kingdoms1600-1920.National Archives of Namibia, Windhoek, Namibia.

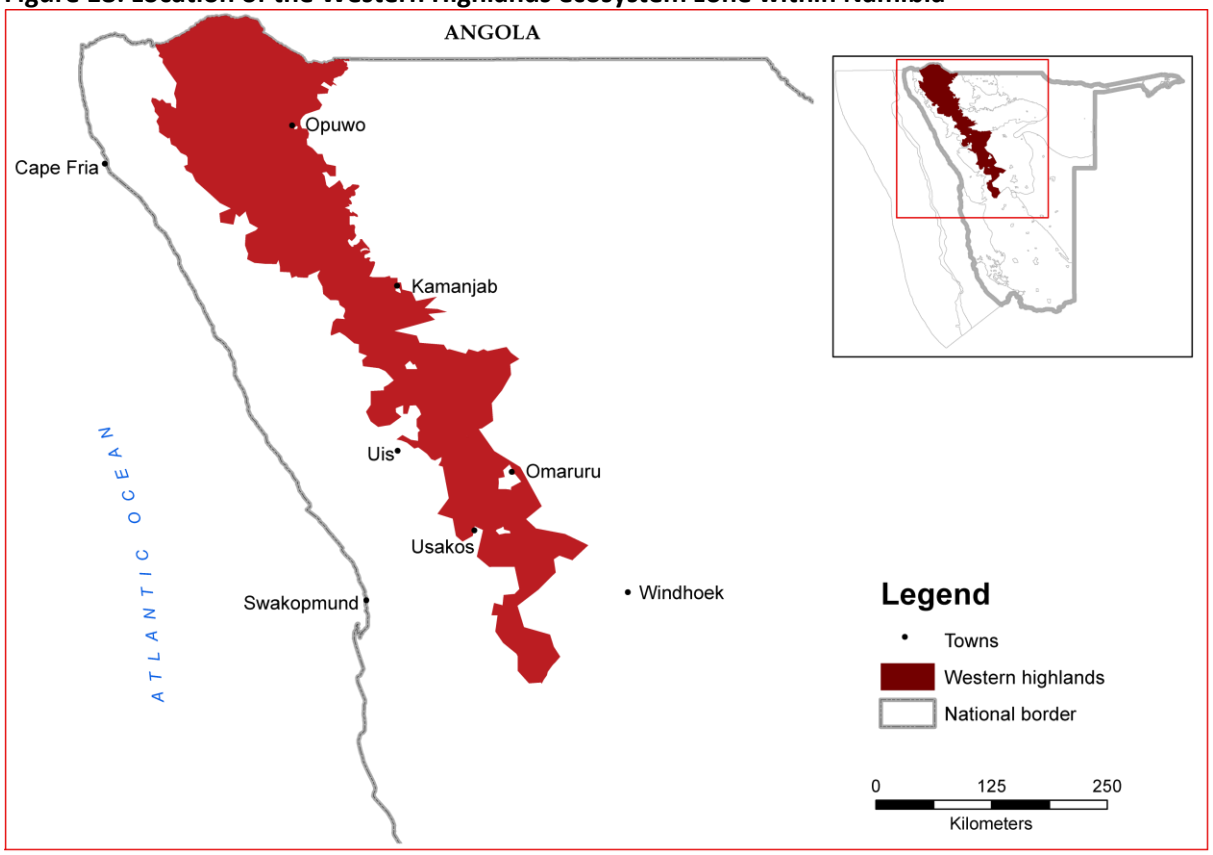
5.8 Western Highlands

5.8.1 Description and assessment of ecosystem zone

5.8.1.1 Main attributes and ecological processes

The Western Highlands cover approximately 70,000 km^2 and incorporate the escarpment belt running between the elevated inland plateau and the coastal plain of the Namib and the Nama Karoo; Figure 18 presents their location within Namibia. Terrain in this zone is rugged and mountainous, lying between 1,000 and 1,900 metres above sea level, dissected by the many tributaries of westward flowing rivers that rise both in this belt and further inland, where surface runoff is relatively high. Soils are generally thin and coarse textured, in some places being absent where bedrock is exposed. The gravelly texture of the soils combined with the sloping terrain makes them highly erodible. The zone includes the Grootberg, Baynes, Zebra, and Erongo Mountains.

Figure 18: Location of the Western Highlands ecosystem zone within Namibia



Annual rainfall in the Western Highlands is usually between 200 mm and 300 mm, although rare years of higher rainfall can give rise to double this level or more. Rain falls in summer thunderstorms, mostly between January and March, and often leads to flows in the river courses that can quickly reach flood proportions after particularly intense storms. These flows in the river courses generally represent the only incidences of surface water in the ecosystem zone, although sources of water occur at springs where the geology brings groundwater to the surface, such as at Sesfontein and Khowarib. The low rainfall coupled with low humidity and warm to hot temperatures, gives rise to a more extreme climate than closer to the coast.

Vegetation in this arid landscape is much more abundant compared to areas to the west. From north of the Ugab River, mopane trees are the dominant plant, with other scattered shrubs and low trees (e.g. *Commiphora*, *Euphorbia*, *Acacia*) growing in the rocky soils. The low rainfall generally does not allow the trees to grow taller than about 2-3 m, and only rarely up to 5 m, so they form low scrubby cover. Taller trees and dense bushes (e.g. ana tree (*Faidherbia albida*), makalani palms (*Hyphaene petersiana*), Salvadora bushes (*Salvadora persica*), tamarisk scrub (*Tamarix usneoides*)) line the river courses where soil moisture is permanently available.

Valleys with some soil accumulation contain more annual and perennial grasses and it is these areas which support relatively greater numbers of wildlife. The mountainous Kaokoveld and the escarpment zone are botanically rich, with high diversity and endemicity. In the southern part of this zone, such as around Karibib and on the western edges of the Khomas Hochland, the vegetation is mainly *Acacia* scrub and grasses, with varying levels of bush thickening.

The relatively higher plant diversity in this zone is due to the variety of micro-habitats associated with mountains and slopes, determined by factors such as varying relief, kinds of rocks, intensity of sunlight and depth of soil. Large and medium sized mammals in the Western Highlands include elephant, black rhino, lion, leopard, mountain zebra, giraffe, oryx and springbok. The escarpment is a zone where many Namibian endemic plants, reptiles, birds and mammals occur.

5.8.1.2 Human activity and population

The largest urban areas in the Western Highlands are Opuwo (7,700), Khorixas (6,800), Omaruru (6,300) and Karibib (5,100). Collectively, the populations of these urban areas have increased by 33% since 2001. The towns of Usakos and Uis lie just outside the zone.

The rural population in the zone has increased from just less than 52,000 in 2001 to about 58,000 in 2011, corresponding to an increase of about 13% and representing a population density of 0.83 people per km^2. Most of the Western Highlands is communal land, while the very south of the zone is private freehold land.

The majority of the northern part of the zone is registered as falling under communal conservancies; parts of more than 30 conservancies fall within the Western Highlands. There are also tourism concessions at Etendeka and Palmwag. A number of freehold conservancies can be found in the areas around Kamanjab and Karibib.

The zone falls within parts of the Kunene and northern Erongo regions. Both of these regions have incidences of poverty lower than the national average, and average rural consumption per capita higher than the national average. There is likely to be significant variation in incomes and consumption within the ecosystem zone, however.

5.8.1.3 Pressures and drivers of change

Table 36: Broad drivers of change and ecosystem-specific pressures in the Western Highlands ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Overgrazing
Exploitation	Abstraction of groundwater; increases in livestock numbers
Pollution	No relevant pressures identified in this zone
Invasive species	No relevant pressures identified in this zone
Climate change	More extreme climatic conditions
Illegal use	Poaching, particularly black rhino

Table 36 relates the six broad categories of drivers of change to specific pressures within the Western Highlands ecosystem zone. The relatively low population density and significant presence of communal conservancies in the north of the zone somewhat limits the extent of major pressures in the Western Highlands. However, as in many of the ecosystem zones described in this report, overgrazing is a significant issue. It is leading to land degradation and a reduction in the productivity of pastures; desertification is becoming an increasing concern.

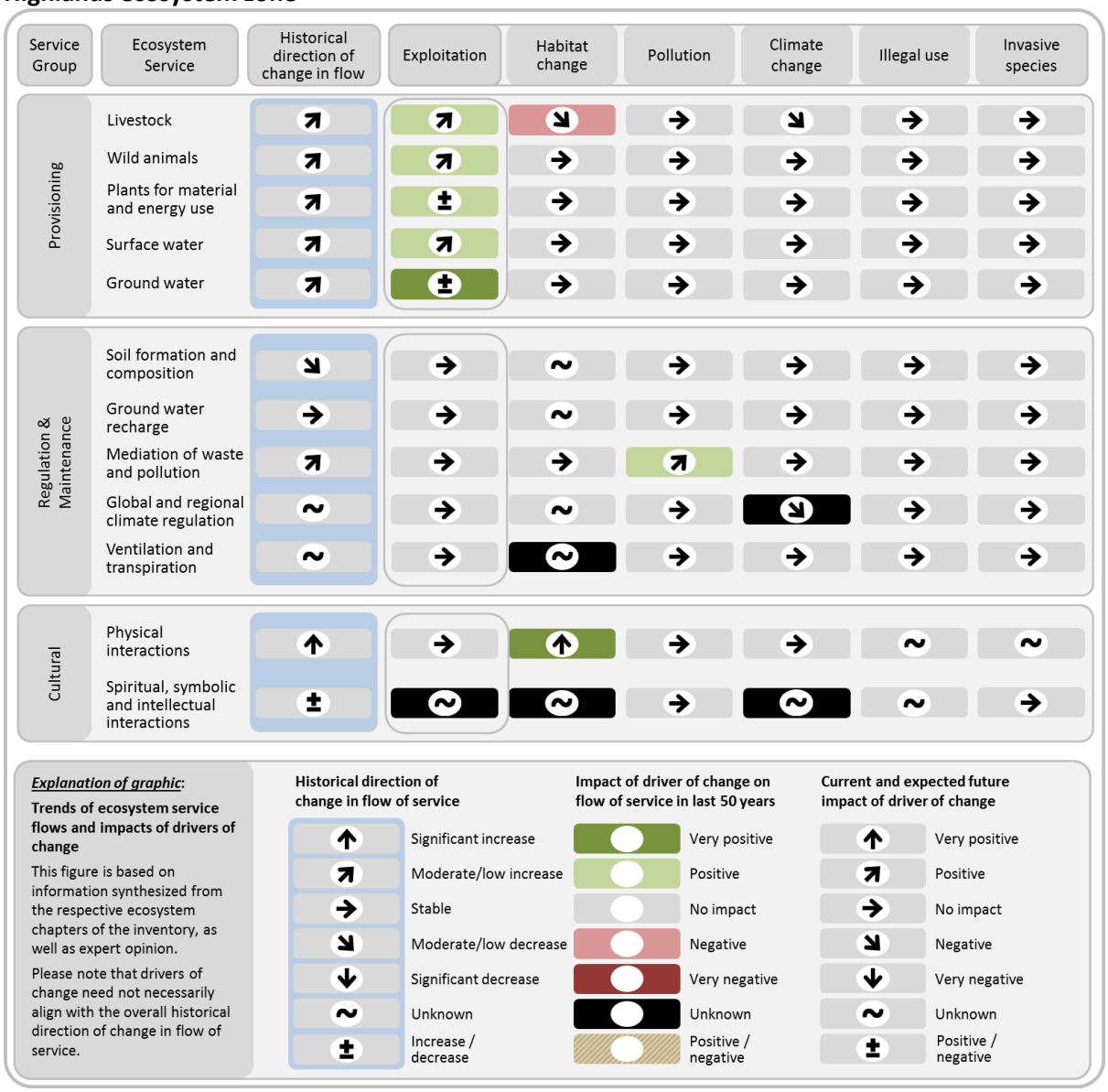
A less significant pressure is the abstraction of groundwater, which is likely within the long-term limits of available supply. There may be abstraction from groundwater compartments that cause a local water supply to dry up, but the aquifer is generally recharged during the next flood event. There is some poaching of wildlife, and notably black rhino, within the zone. This has increased in recent years, and represents a concerning trend.

Climate change could result in increased aridity, but the exact effects are largely uncertain. The effects of development and human activity on the Angolan side of the Kunene are also uncertain; this could represent potential pressures under exploitation and pollution.

5.8.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Western Highlands ecosystem zone. Figure 19 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 19: Overview of flows of services and impacts from drivers of change in the Western Highlands ecosystem zone



5.8.2.1 Provisioning

Table 37 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Western Highlands (and which are comparable to those classes specified in Figure 19). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 37: Overview of provisioning services in the Western Highlands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Cultivated crops	Crops such as maize	Local	Consumptive use
Reared animals and their outputs	Meat and dairy from livestock (cattle, goats, fait-tailed sheep)	Local	Consumptive use
Reared animals and their outputs	Cattle as capital	National	Option
Wild animals and their outputs	Meat from wildlife	Local	Consumptive use
Surface water for drinking	Sources of drinking water at springs such as Sesfontein, Khowarib	Local	Consumptive use
Groundwater for drinking	Drinking water pumped from aquifers in most of the ephemeral rivers and in hard rock fractures	Local	Consumptive use
Fibres and other materials from plants, algae and animals for direct use or processing	Skins, horns, bones and trophies from livestock and wildlife	International	Consumptive use
Fibres and other materials from plants, algae and animals for direct use or processing	Ochre for Himba; wood for construction of houses	Local	Consumptive use
Fibres and other materials from plants, algae and animals for direct use or processing	INP - *Commiphora* resin for beauty products	International	Consumptive use
Surface water for non-drinking purposes	Sources of water for domestic use and livestock and wildlife at springs	Local	Consumptive use
Groundwater for non-drinking purposes	Water for domestic and industrial use in settlements/towns, and for livestock and wildlife pumped from aquifers	Local	Consumptive use
Surface water for non-drinking purposes	Water for domestic and industrial use in settlements/towns	Regional	Consumptive use
Plant-based resources	Wood fuel	Local	Consumptive use
Animal-based energy	Donkeys for transport	Local	Consumptive use

Description

The main land use in the Western Highlands is the farming of livestock, predominantly cattle and goats but also with some fat-tailed sheep, from which meat and dairy products are derived. Wildlife is also hunted as a source of meat, while cattle-keeping is also practiced in the zone. Crops such as maize are grown for own use in river beds in a few areas.

Villages, settlements and towns have grown around permanent water points such as springs (e.g. Sesfontein), boreholes (e.g. Khorixas) or places on ephemeral rivers where water is readily available (e.g. Omaruru), and sparsely scattered homesteads outside of villages are all dependent on a nearby water source. These sources are used to provide water for drinking and domestic use as well as to

support livestock and wildlife. Surface water is also pumped from the Kunene to the northern regions of the zone, but only to a very limited extent.

Natural materials from plants and animals are widely utilised throughout the zone. Wood is used as a construction material for houses as well as for fuel for cooking and providing heat, while INPs such as *Commiphora* are harvested as an input for the production of beauty products. Although not biotic, the Himba in the zone harvest ochre which is crucial to protect them from the sun. Products derived from animals include skins, hides, horns, bones and trophies, while donkeys are used as a form of transport in some areas.

Affected population

The relevant population for the provisioning services relating to nutrition, water, materials and energy is almost entirely local, as they are generally used at the point of extraction or harvesting. Exceptions are INPs and animal products such as trophies and skins that may be processed and exported internationally. Cattle kept as capital is relevant to national populations as owners often live outside of the zone.

Change in flow over past 50 years

The flows of all provisioning services in this zone are estimated to have increased in recent decades; this is primarily as a result of increased human populations and exploitation. The services demonstrating the most significant upward trends include livestock farming and keeping, hunting wildlife for meat, surface water from the Kunene and groundwater for drinking and non-drinking purposes.

Pressures and expected impacts on flow of service

The exploitation of provisioning services relating to food are expected to continue rising, but perhaps at slower rates as rural populations grow more slowly than in recent decades. Rangeland deterioration as a result of a very fragile ecosystem zone being overgrazed is expected to continue, further reducing carrying capacities particularly of cattle. Climate change could also exacerbate this impact if the area becomes even more arid. Cattle keeping is expected to continue increasing as this is driven by urban populations, often outside of the zone.

The exploitation of sources of surface and groundwater are expected to continue increasing in line with growing populations, particularly so with regard to water from the Kunene for urban populations in Opuwo. The extent of the increase in the exploitation of groundwater is unclear as some of these aquifers may have been overexploited.

The use of wood for the construction of houses is also expected to continue, albeit at a reduced rate; similar trends are expected for the use of wood as fuel and ochre for the Himba. The exploitation of animal products, particularly trophies and skins for processing and sale, is likely to continue increasing, as is the use of *Commiphora* for beauty products. The use of donkeys for transport is not expected to change significantly.

5.8.2.2 Regulation and maintenance

Table 38 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Western Highlands.

Table 38: Overview of regulation and maintenance services in the Western Highlands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect use
Ventilation and transpiration	Vegetation enabling air ventilation	Regional	Indirect use
Weathering processes	Decomposition/mineralisation of dead organic material, nitrification	Regional	Indirect use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure in the river beds	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances is generated largely at the ecosystem level by the absorption of pollutants and the dilution of gases into the atmosphere. The mediation of flows relates to both liquids (with regard to groundwater recharge) and gases (through vegetation enabling air ventilation). There are two groups of services relating to the maintenance of physical, chemical and biological conditions: soil formation and composition (through both the decomposition/mineralisation of dead organic material and nitrification, as well as the maintenance of the fertility of soils, nutrient storage and their soil structure) and atmospheric composition and climate regulation (through carbon sequestration and the maintenance of regional precipitation/temperature patterns).

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of liquid and gaseous flows. The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level.

Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

The absorption and dilution of pollutants in the ecosystem zone is thought to have increased as a result of slightly increased pollution from higher populations and more human activity, although this is likely to be of limited importance. Overgrazing is thought to have resulted in rangeland deterioration, and consequently a decline in the fertility of soils as well as their erosion in places, particularly of deep alluvial sediments within river valleys. This has also led to losses of woodland and some arable soils.

There are not thought to have been any noticeable changes to groundwater recharge, the decomposition/mineralisation of dead organic material, or carbon sequestration in the ecosystem zone. The overall effects on vegetation enabling air ventilation and the maintenance of regional precipitation/temperature patterns are not well understood.

Pressures and expected impacts on flow of service

The absorption and dilution of pollutants is expected to continue increasing at a similar rate as human activity in the ecosystem zone expands, although it is still likely to be a relatively insignificant service. The negative effect on the fertility of soils is expected to continue, although the extent of this is unclear; desertification could ultimately have severe detrimental impacts on this service. The service relating to the maintenance of regional precipitation patterns could decline as a result of climate change. The effects of pressures, particularly relating to habitat change, on the other regulation and maintenance services is largely uncertain.

5.8.2.3 Cultural

Table 39 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Western Highlands.

Table 39: Overview of cultural services in the Western Highlands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Wildlife viewing; landscape appreciation; appreciation of rock art (e.g. Twyfelfontein); hiking; cultural and heritage-based tourism	International	Non-consumptive use
Physical use of land-/seascapes in different environmental settings	Recreational hunting	International	Consumptive use
Scientific	Variety of research, e.g. desert-adapted elephant/giraffe/lion	International	Non-consumptive use
Heritage, cultural	Brandberg rock paintings (white lady); Twyfelfontein World Heritage Site; Himba; Damara; Kaokoland and Damaraland homelands	National	Non-consumptive use; bequest; existence
Aesthetic	Brandberg; Representations of Himba; Kaokoveld	International	Non-consumptive use
Symbolic	Himba as representative of parts of Namibia	International	Non-consumptive use
Sacred and/or religious	Rituals relating to communication with ancestors	National	Non-consumptive use
Existence	Relating to wildlife, landscapes, Himba lifestyle	International	Existence
Bequest	Relating to wildlife, landscapes, Himba lifestyle	International	Bequest

Description

Non-consumptive recreational tourism in the zone is primarily based around landscape appreciation, and wildlife viewing. Consumptive tourism relates primarily to recreational hunting and hiking (e.g. at Brandberg). Wildlife in the zone and neighbouring ecosystem zones also gives rise to a range of research, particularly with regard to black rhino, elephant, lion and giraffe that live in the wider Kunene region, and how humans interact with them.

There are highly significant cultural and heritage services in the ecosystem zone. The Twyfelfontein World Heritage Site has been inhabited for more than 6,000 years and contains in excess of 2,500 rock engravings.

Along with neighbouring ecosystem zones, the Western Highlands are home to the Himba; it also incorporates part of the previous homelands of Kaokoland and Damaraland. Specific sacred sites in the zone are of importance to the Himba and their rituals involving communicating with their ancestors. The great number of rock engravings at Twyfelfontein has led to its proclamation as a

World Heritage Site, bringing value from tourists' non-consumptive use of a cultural resource. There are also lesser services relating to aesthetic representations of the ecosystem zone and of Namibia. Bequest and existence services may relate to the wildlife within the zone, as well as the landscapes and the Himba lifestyle.

Affected population

Tourists to the zone are primarily international visitors; scientific, aesthetic, symbolic and the existence and bequest services relating to wildlife, the Himba and the landscapes are also relevant to international populations. The heritage, cultural and spiritual services are relevant to the local and regional Himba population, but also to those who may now live nationally, outside of the zone.

Change in flow over past 50 years

Recreational tourism has increased significantly in recent decades; scientific services are also thought to have increased. The flows of other cultural services are not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone; this is likely to be as a result of a combination of improved access to some areas and the continued development of some facilities. Poaching could represent a threat in the longer term to recreational tourism, but at its current level it is not thought to be of significance. The effects of pressures on other cultural services are generally poorly understood.

5.8.2.4 Interactions between ecosystem services

Overgrazing in the zone could be leading to the loss of rangeland as a result of soil erosion, and potentially increasing the rate of desertification. This would in turn reduce livestock carrying capacity. The already marginal nature of many of the rangelands in the zone increases this risk. There are also linkages with other neighbouring ecosystem zones; the riverbeds in this zone extend westwards to the coast and are crucial wildlife movement corridors for species such as elephant.

5.8.3 Criteria for prioritisation of ecosystem services

5.8.3.1 Current and future expected impacts on the flow of the service

No major declines in ecosystem services in the zone are expected; there are some pressures from land degradation on the carrying capacity of livestock, and resulting threat of desertification, but at current levels this is unexpected to restrict the delivery services relating to livestock.

5.8.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

There are limited threats from unsustainable water use in this ecosystem zone. At the current rate of abstraction, groundwater is not overexploited.

Expansion of urban areas and increasing industrialisation

There are some possible future developments that could affect the zone; these include a hydropower dam on the Kunene River at the Baynes Mountains site, and a port at Cape Fria. These

would involve significant development of road and/or rail infrastructure, and a possible rail link running inland from Cape Fria. Many ecosystem services would be put under pressure from increased use and easier road access into remote areas.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the ecosystem zone to be used for agriculture.

Rapid expansion of mining and prospecting

There are limited threats from the rapid expansion of mining and prospecting in this ecosystem zone. The Navachab gold mine near Karibib is in this zone. Extensive prospecting is ongoing; there is a proposed rare earth mine near Khorixas.

Unsustainable land management practices

Overgrazing is thought to be causing land degradation in this ecosystem zone.

Uncontrolled bush fires

Uncontrolled bush fires are not a threat in this ecosystem zone.

Alien invasive species

There are no significant threats from alien invasive species in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

Poaching is a growing concern in the ecosystem zone particularly with regard to black rhino. This could impact on tourism if it accelerates.

Human-wildlife conflict

There is some human-wildlife conflict in the zone with predators and large mammals such as elephant. This conflict is not always tolerated by rural residents as it can affect services related to livestock.

5.8.3.3 Economic importance (current and potential)

Recreational tourism (including hunting) through communal conservancies is an important source of cash income in the ecosystem zone, occurring mainly within the many conservancies. Other services are generally not commercialised.

5.8.3.4 Affected population (size and socio-economic characteristics)

The provision of water is relevant to significant populations, particularly because of its relative scarcity. Livestock keeping and farming is important to most of the rural population in the zone. Cultural services relating to the Himba may also be prioritised within this criterion.

5.8.3.5 Availability of data

The numbers of (formal) tourists staying in different types of accommodation should be available from the operators of lodges and campsites. Conservancies conduct game counts on an annual basis. Research conducted in the zone should be able to provide some data on regulation and maintenance services.

5.8.4 References

Barnard, P. (ed.) 1998. Biological diversity in Namibia: a country study. Windhoek: Namibian national Biodiversity Task Force.

Giess, W. 1971. A preliminary vegetation map of South West Africa. Dinteria 4: 1-114.

Harris, M. 2015. Personal communication on status of groundwater reserves in settlements along Namibian escarpment.

Jacobson, P.K., K.M.Jacobson and M.K.Seely. 1995. Ephemeral rivers and their catchments: Sustaining people and development in western Namibia. Desert Research Foundation of Namibia, Windhoek.

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.

NACSO. 2010. Assessment of climate change impacts and adaptation options for Namibia's CBNRM programme in Kunene and Caprivi. Unpublished report compiled by Southern African Institute for Environmental Assessment.

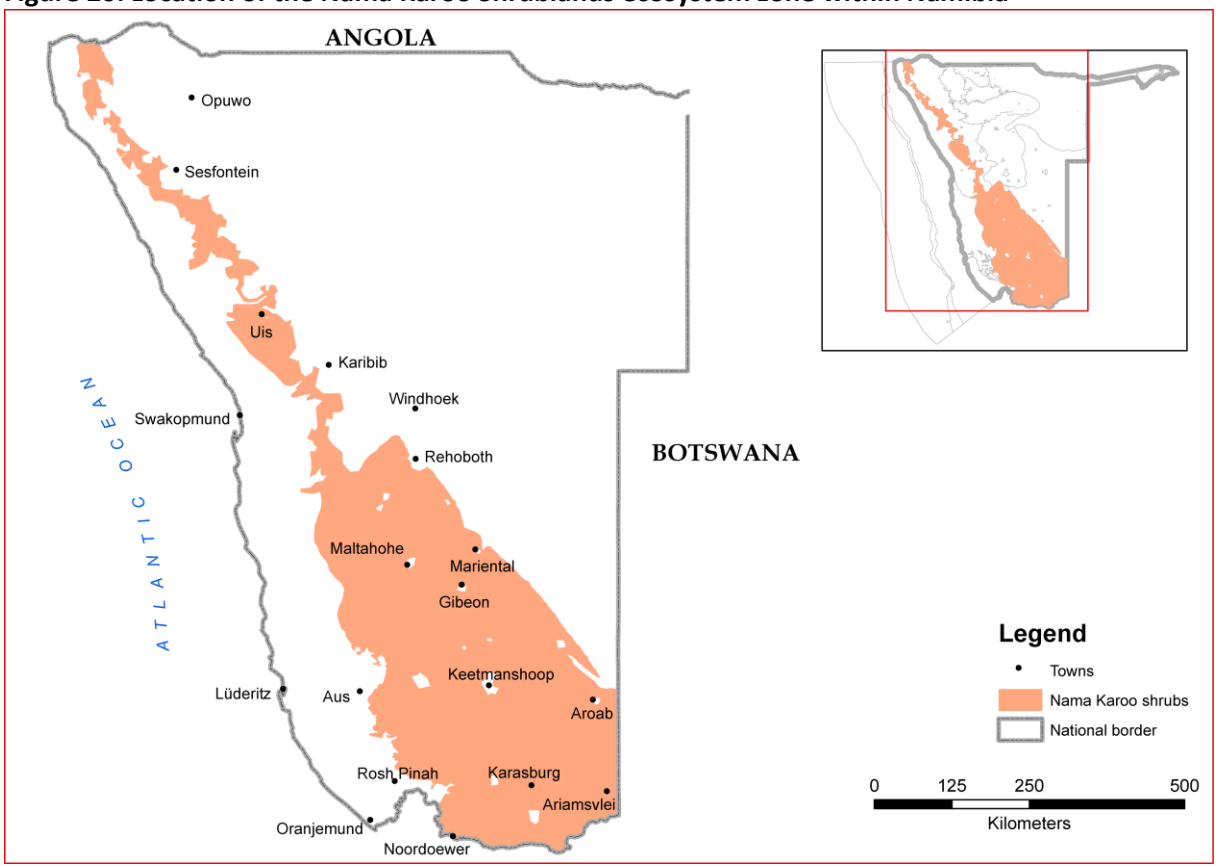
5.9 Nama Karoo Shrublands

5.9.1 Description and assessment of ecosystem zone

5.9.1.1 Main attributes and ecological processes

The Nama Karoo Shrublands is the largest of the ecosystem zones described in this report, at 196,000 km^2; it is mapped in Figure 20. The landscape is mainly flat undulating plains, broken in places by ephemeral rivers and some mountains. The tributaries of the Fish and Orange Rivers incise the terrain in the central and southern parts of the zone, and approaching the Orange River to the south there is very dissected and rugged terrain, especially along the Fish River Canyon and in the Huns Mountains immediately to the west of it. The Fish River basin covers much of the southern block of the Nama Karoo.

Figure 20: Location of the Nama Karoo Shrublands ecosystem zone within Namibia



Mountain ranges in the Nama Karoo include those along the escarpment in the southern half of the country, such as the Huib-Hoch Plateau, Tiras, Schwarzrand, Tsaris, and Naukluft Mountains. Inselbergs in the central part of the country, including Spitzkoppe and Brandberg, are included in this zone. Also in the south are the Groot Karas and the Klein Karas Mountains south of Keetmanshoop, the Brukkaros inselberg and a small escarpment called the Weissrand running south-east from Mariental, which forms the border of the zone in the south-east.

The zone extends north-westwards in a thin broken strip parallel to, and on the lower ground contiguous with, the Western Highlands. Along the western edge of the Nama Karoo, where it borders the Namib proper, it is informally called the 'pro-Namib'.

The plains are mostly covered in grasses and low shrubs, growing in shallow, stony soils, while ephemeral water courses support taller plants such as bushes and Acacia trees. A dominant thorny shrub over much of the Nama Karoo in the south is 'driedoring' (*Rhigozum trichotomum*), which occurs on both stony and sandy soils. Some areas are encroached with low *Acacia nebrownii* trees, while many water courses support dense thickets of alien *Prosopis* trees.

In the pro-Namib the ground is either bare or has a thin covering of annual and perennial grasses, dotted with occasional shrubs. Shallow washes and ephemeral streams, with slightly higher soil moisture, support a higher density of shrubs as well as trees. These thin lines of vegetation create a branching network over the plains.

Average annual rainfall is very low in Nama Karoo, not exceeding 200 mm except in the Rehoboth area where the average is 300 mm. The south-western part of the Nama Karoo receives some of its rain in winter, while most of this zone has summer rain which falls in heavy thunderstorms. The Rehoboth area and the Naukluft Mountains southwest of Rehoboth receive enough rain to feed the upper reaches of the Fish River, Namibia's largest ephemeral river.

Historically, the plains of the Nama Karoo Shrublands in southern Namibia supported large herds of wildlife, predominantly springbok, oryx and ostrich, but also giraffe, black rhino and lion, similar to the situation today in the Northern Namib. Nowadays, Namibia's 'south' is primarily an area for small stock farming, and much of the area is devoted to Dorper sheep and Boer goats which graze on the large farms. Cattle numbers are increasing and replacing sheep and goats, but the veld is better suited to small stock. Wild ungulates (e.g. springbok, oryx, kudu) co-exist on the farms and are an important complement to livestock for local livelihoods, with some farms turning completely to wildlife as the main land use. An important aspect of farming of small stock is that there is low tolerance for predators such as jackal, caracal, cheetah and leopard, and these animals are completely absent over large areas due to dedicated and ongoing measures to eradicate them.

The thin belt of the Nama Karoo Shrublands running next to the Northern Namib is also used for extensive livestock farming under predominantly communal land use, but carries more of the original wildlife as well.

The escarpment is known for high endemism rates, and there are also clusters of relatively higher endemism rates centred on the Karas Mountains and Brukkaros Mountain. Groups with high proportions of Namibian endemics in the Nama Karoo are invertebrates (including a large number of solifuges and beetles) and reptiles (particularly geckos).

5.9.1.2 Human activity and population

The largest urban area in the Nama Karoo Shrublands is Rehoboth, with a population of 29,000 that has grown approximately 35% since 2001. Other relatively large to medium sized towns include Keetmanshoop (21,000) and Mariental (12,500) which have been growing at slightly slower rates (33% and 27%, respectively). Urban growth has been comparatively faster in the larger towns than in the smaller ones.

Rural populations in this zone are widespread but thinly distributed, and are estimated to have decreased from 52,000 to 37,000 between 2001 and 2011 (a fall of almost 30%, the greatest such decline in rural populations in Namibia) as rural to urban migration has increased. Population

densities in this zone are the fourth lowest in Namibia, at around 0.19 people per km^2. The large area covered by the zone makes it difficult to present representative socio-economic characteristics; however, most of the zone falls within the Hardap and Karas region, which have incidences of poverty below the national average and average rural consumption per capita significantly above the national average.

Much of the northern strip of the Nama Karoo, particularly north of Uis, falls within a number of different communal conservancies, as well as the Palmwag Tourism Concession. The main block towards the south is primarily privately held farmland, and includes the freehold Tiras Mountain Conservancies and the Namibrand private nature reserve. All five communal conservancies situated in the southern half of the country (Oskop, !Khob !Naub, //Gamaseb, !Gawachab and !Han /Awab) are located within the zone. Three State protected areas at least partially fall within the zone: the Ai-Ais Hot Springs, the Naute Recreation Resort south of Keetmanshoop and the Hardap Recreation Resort just outside Mariental. Private reserves such as Namibrand that adjoins the Namib Naukluft Park, and freehold conservancies, also make wildlife/conservation their primary land-use.

5.9.1.3 Pressures and drivers of change

Table 40: Broad drivers of change and ecosystem-specific pressures in the Nama Karoo Shrublands ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Overgrazing; bush thickening
Exploitation	Abstraction of surface water from the Orange River upstream in South Africa
Pollution	Pollution of Orange River upstream in South Africa; pollution of surface water from irrigation schemes; contamination of boreholes
Invasive species	Prosopis in river beds
Climate change	Increased aridity
Illegal use	Poaching a relatively minor threat in northern strip

Table 40 relates the six broad categories of drivers of change to specific pressures within the Nama Karoo ecosystem zone. The major pressure in this zone is from overgrazing, which has resulted in a gradual decline in rangeland productivity.

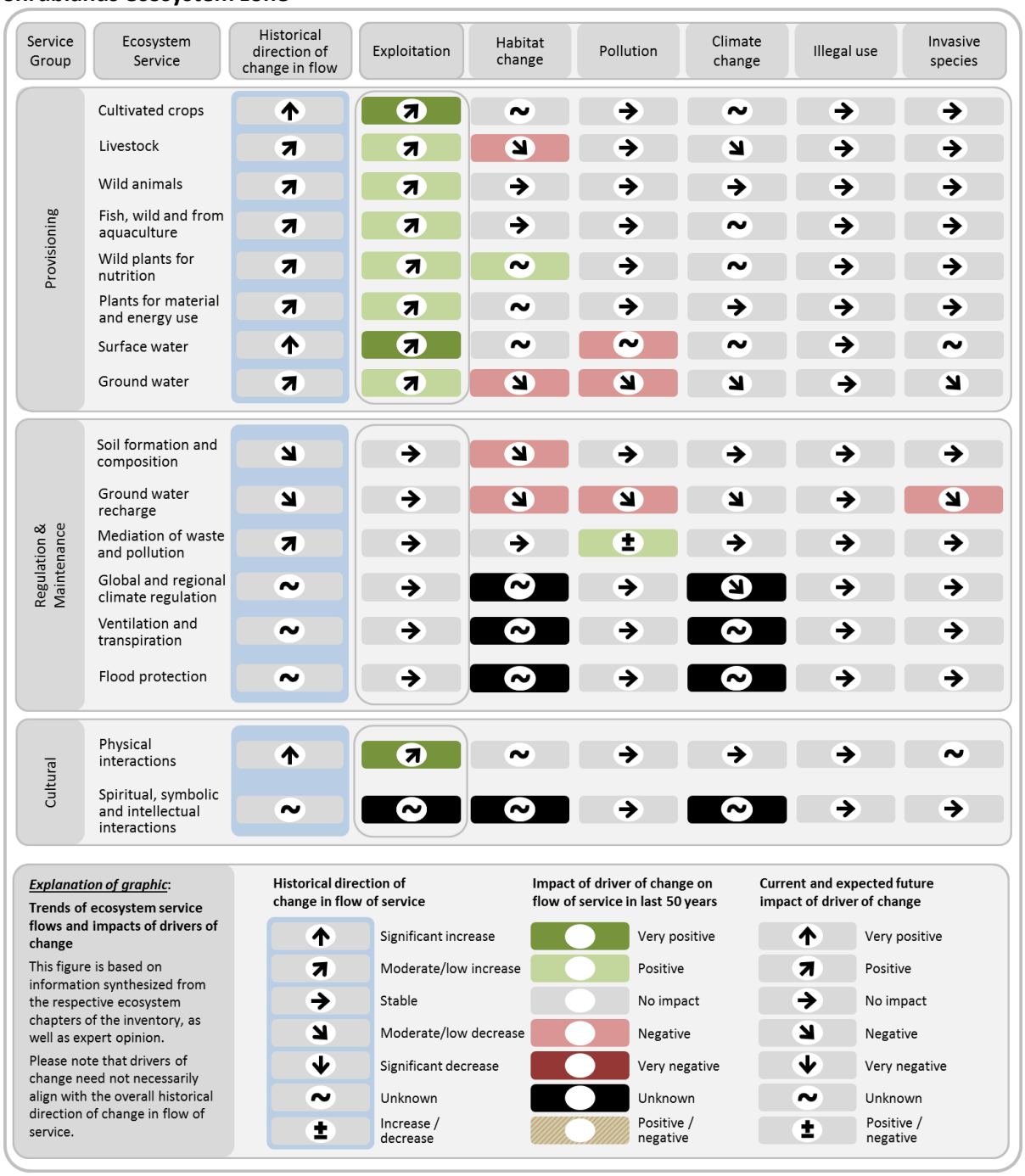
Less significant pressures arise in a variety of ways. Habitat change is also occurring as a result of bush thickening (in particular of *Rhigozum* and *A.nebrownii*), which in turn is reducing recharge rates, while infestations of *Prosopis* trees (an invasive species) in river beds are reducing river flows. The abstraction and pollution of water in the Orange River upstream in South Africa has reduced flows and water quality in Namibia; the impacts of this are mainly at the coast (see Section 5.12.4).

Pollution of surface water in Namibia is occurring as a result of return flows from irrigation schemes (e.g. from Hardap farms into the Fish River); this may be contributing to the growth and extent of *Prosopis*. There is some contamination of boreholes where surface runoff polluted by dung flows into the borehole. Climate change could result in a more arid climate, but the precise effects are unclear; it is likely though that increased carbon dioxide levels will further contribute to bush thickening.

5.9.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Nama Karoo Shrublands ecosystem zone. Figure 21 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 21: Overview of flows of services and impacts from drivers of change in the Nama Karoo Shrublands ecosystem zone



5.9.2.1 Provisioning

Table 41 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Nama Karoo Shrublands (and which are comparable to those classes specified in

Figure 21). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 41: Overview of provisioning services in the Nama Karoo Shrublands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Cultivated crops	Vegetables, cereals, orchards, vineyards	National	Consumptive use
Reared animals and their outputs	Meat and dairy from livestock (cattle, goats, sheep)	National/local	Consumptive use
Wild animals and their outputs	Meat from wildlife	National	Consumptive use
Animals from in-situ aquaculture	Fish farm near Mariental	National	Consumptive use
Surface water for drinking	Water for drinking from dams	Regional	Consumptive use
Surface water for drinking	Drinking water pumped from the Orange River	Regional	Consumptive use
Groundwater for drinking	Drinking water pumped from aquifers	Local	Consumptive use
Fibres and other materials from plants, algae and animals for direct use or processing	Leather, skins, horns and trophies from livestock and wildlife	International	Consumptive use
Materials from plants, algae and animals for agricultural use	Fodder	Regional	Consumptive use
Surface water for non-drinking purposes	Water for domestic/industrial use, livestock and irrigation from dams	Regional	Consumptive use
Surface water for non-drinking purposes	Water for domestic and small-scale industrial use, livestock and irrigation pumped from the Orange River	Regional	Consumptive use
Groundwater for non-drinking purposes	Water for domestic and small-scale industrial use, livestock and wildlife pumped from aquifers	Local	Consumptive use
Plant-based resources	Wood fuel	Local	Consumptive use

Description

There are a number of services that are used to provide food in the Nama Karoo. To the south of the zone, there are intensive irrigation schemes that support the production of maize, wheat, lucerne, vegetables, fruit orchards (e.g. dates), and vineyards. Meat and dairy is farmed from cattle, goats and sheep, while wildlife is also hunted for meat. There is a fish farm near Mariental. Veld foods are present but generally not a prominent source of nutrition. Cattle are also kept as capital in the northern areas of the zone.

At the border with South Africa, surface water is pumped from the Orange River to provide water for drinking and non-drinking purposes, including domestic, industrial and commercial use, and irrigation. Surface water is collected in dams (Hardap and Naute, as well as Neckartal when it becomes operational) and used for similar purposes, as well as for livestock. Groundwater is

pumped from aquifers for drinking purposes, as well as for domestic use and to support livestock and wildlife; this is the only source of water in the thin strip representing the northern section of the zone.

Fodder is an important resource in the zone, found mainly on the open plains of grasses. Wood is harvested in the zone for use as fuel, and animal products from livestock and wildlife include leather, skins, hides, horns and trophies.

Affected population

Provisioning services relating to food are generally produced commercially, and thus are relevant at the national level, although some cattle farming in the north is purely for local consumption. Cattle keeping that occurs in the north of the zone is relevant nationally as the owners often live elsewhere.

Surface water from both the Orange River and dams in the zone is relevant to regional populations, while groundwater pumped from aquifers, especially in the northern block, is mainly relevant to local populations. Wood fuel is also generally used within the vicinity of its harvesting. Fodder is used regionally, while some animal products such as trophies are exported internationally.

Change in flow over past 50 years

The flows of all provisioning services in this zone are estimated to have increased in recent decades, primarily due to increased population and exploitation. The services demonstrating the most significant upward trends include farming of crops and the use of surface water for irrigation purposes.

Pressures and expected impacts on flow of service

The exploitation of provisioning services relating to food is expected to continue growing as national demand for these products increases. The growth of the production of meat and dairy from cattle and goats may slow as land users incorporate more wildlife (particularly in the southern section); this is also likely to lead to increased production of meat from wildlife.

Habitat change as a result of overgrazing leading to rangeland degradation may further restrict the capacity of the ecosystem zone to provide for the production of meat and dairy from cattle and goats, as well as having smaller but negative impacts on the keeping of cattle in the northern section. The effects of habitat change on the production of cultivated crops are unclear. Climate change has the potential to compound the negative effects of habitat change; increased temperatures and the possibility of greater rainfall variability could lead to increased demand for irrigation water.

Demand for water, particularly for drinking, domestic, small-scale industrial and commercial use, is expected to continue increasing rapidly; this is likely to be primarily drawn from the dams and the Orange River. However, surface river flows are likely to decline as a result of continued bush thickening and the infestation of *Prosopis* in river beds, consequently reducing flows into dams. However, at current rates, these factors are unlikely to restrict the delivery of surface water. Return flows from irrigation schemes (for example from Hardap farms into the Fish River) results in water

pollution, but how this pressure develops is uncertain as it depends on whether farmers allow return flows or limit them. Increased pollution of water in the Orange River from upstream uses in South Africa is also expected, although this is not likely to have any effect on the delivery of the service. The effect of climate change is unclear.

Groundwater is the main source of water for livestock and wildlife, and its exploitation is expected to continue growing. However there are also a number of threats to the continue delivery of this service. Habitat change through bush encroachment is reducing groundwater recharge (see Section 4.3), increasing the risk of overexploiting the resource. There is some contamination of boreholes occurring at livestock watering points where surface runoff is polluted by dung flows into the boreholes; this could get more severe as surface runoff is increased.

Offtake of wood for fuel is expected to continue, and increased bush in the zone could lead to greater capacity. Exploitation of fodder is expected to continue, but the effects of increased bush encroachment on this service are not clear. Utilisation of wildlife and livestock for leather, skins, horns and trophies is expected to continue.

5.9.2.2 Regulation and maintenance

Table 42 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Nama Karoo Shrublands.

Table 42: Overview of regulation and maintenance services in the Nama Karoo Shrublands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Bio-remediation by micro-organisms, algae, plants, and animals	Purification of water by aquatic micro-organisms	Regional	Indirect use
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere; dilution of nutrients in rivers	Regional	Indirect use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect use
Hydrological cycle and water flow maintenance	Protection from flood waters	Local	Indirect use
Ventilation and transpiration	Vegetation enabling air ventilation	Regional	Indirect use
Weathering processes	Decomposition/mineralisation of dead organic material, nitrification	Local	Indirect use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure	Local	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances occurs through the absorption of pollutants and the dilution of gases into the atmosphere, as well as the purification of water by aquatic micro-organisms and the dilution of pollutants in rivers. The purifying role of these micro-organisms can be particularly important given the return flows from irrigated lands, which carry high nutrient loads.

The mediation of flows relates to both liquids (with regard to groundwater recharge and flood protection) and gases (through vegetation enabling air ventilation). There are two groups of services relating to the maintenance of physical, chemical and biological conditions: soil formation and composition, (through both the decomposition/mineralisation of dead organic material and nitrification, as well as the maintenance of the fertility of soils, nutrient storage and their soil

structure) and atmospheric composition and climate regulation (through carbon sequestration and the maintenance of regional precipitation/temperature patterns).

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the groundwater recharge and vegetation enabling air ventilation. The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level; flood protection is also mainly of relevance at the local level. Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

The absorption and dilution of pollutants in the atmosphere and by vegetation is thought to have risen as a result of increased pollution from bigger populations and more human activity, although this is likely to be of limited importance.

Groundwater recharge is thought to have declined as a result of bush encroachment. The flood protection service is uncertain – in river beds inundated with *Prosopis* trees, flow dynamics will have changed from the blocking effect of the invader trees and the increased transpiration of groundwater. On the other hand, recent Mariental floods have been blamed on blockages by reeds downstream of Hardap Dam, but it is likely that downstream floods have become less frequent due to the Dam. Certainly, this impact has been predicted downstream of the Neckartal Dam when it is completed.

Overgrazing on relatively marginal rangelands has resulted in their deterioration, and hence reductions in the services relating to soil formation and composition. Changes in carbon sequestration and micro and regional climate regulation are not well understood; the former largely because of the competing impacts of the loss of rangeland and increased bush.

Pressures and expected impacts on flow of service

The absorption and dilution of pollutants is expected to continue increasing at a similar rate as human activity in the ecosystem zone continues to grow, although it is still likely to be a relatively insignificant service. If abstraction of water from the Orange River increases significantly, this could reduce flow rates and consequently the ability of the river to dilute pollutants. The service of water purification by aquatic micro-organisms may be under pressure from increased water abstraction, but the effect of pollution is unclear because it depends partly on what happens upstream and also whether farmers choose to allow return flows or limit them.

The rate of groundwater recharge is expected to continue to decline as a result of bush encroachment; this may be compounded by pollution which fosters the growth of plants that reduce recharge. Flood protection could be even further reduced if riverine vegetation continues to decrease (especially if the water table drops). The services relating to soil formation and

composition are also expected to decline further as a result of continued overgrazing and rangeland degradation.

Micro and regional climate regulation is likely to be negatively impacted by climate change if rainfall is reduced, but the extent and timing of these impacts is not clear. The effects of the pressures on carbon sequestration and vegetation enabling air ventilation are unclear.

5.9.2.3 Cultural

Table 43 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Nama Karoo Shrublands.

Table 43: Overview of cultural services in the Nama Karoo Shrublands ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Wildlife viewing; landscape appreciation; walking	International	Non-consumptive use
Physical use of land-/seascapes in different environmental settings	Recreational hunting	International	Consumptive use
Scientific	Variety of research, e.g. desert-adapted elephant/giraffe/lion	International	Non-consumptive use
Heritage, cultural	Himba; Rehoboth Basters; Nama; Damara, Rock art	National	Non-consumptive use; bequest; existence
Existence	Relating to wildlife, landscapes, various cultures	International	Existence
Bequest	Relating to wildlife, landscapes, various cultures	International	Bequest

Description

Recreational tourism has increased in importance in recent decades, with farmers shifting land uses to incorporate wildlife. This has been to exploit demand for consumptive and non-consumptive wildlife-based tourism in the zone. Recreational tourism also involves hiking, walking and landscape appreciation. In conjunction with neighbouring ecosystem zones, research is undertaken in the zone; in the northern section this includes research on similar wildlife species as discussed in the Western Highlands (Section 0).

The highest point in Namibia, the Brandberg, is also in the ecosystem zone. A number of rock paintings, including the famous "White Lady" have been found in the Brandberg National Monument Area, which is on the tentative list for consideration for World Heritage Status.

The zone encompasses at least parts of a number of former homelands: Namaland, Damaraland, Rehoboth (Basterland) and Kaokoland. As a result there are heritage and cultural services associated with these aspects. Bequest and existence services may relate to the wildlife within the zone (particularly so in the northern part), as well as the landscapes and the various cultures and lifestyles within the zone.

Affected population

Tourists to the zone are primarily international visitors; scientific, existence and bequest services relating to wildlife, the various cultures and the landscapes are also relevant to international populations. The heritage and cultural services are relevant nationally to populations living across Namibia.

Change in flow over past 50 years

Recreational tourism has increased significantly in recent decades; scientific services are also thought to have increased. The flow of services relating to other cultural services is not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone; this is likely to be as a result of the continued development of wildlife land uses in the zone as well as more general factors such as increased overall tourist arrivals. The effects of pressures on other cultural services are generally poorly understood.

5.9.2.4 Interactions between ecosystem services

As in many other ecosystem zones, overgrazing has reduced rangeland productivity which has in turn reduced livestock carrying capacity. There is also a feedback loop evident with regard to the abstraction of surface water for irrigation and the production of crops. The returns flows can pollute at the source or further downstream.

There are also interactions with neighbouring ecosystem zones. Use of water from the Orange River upstream in South Africa can reduce downstream flows in Namibia, while pollutants are also transported between the countries. Flows and water quality in the Orange River also affect the Succulent Karoo ecosystem zone and the Coastal and Near-Shore zone.

5.9.3 Criteria for prioritisation of ecosystem services

5.9.3.1 Current and future expected impacts on the flow of the service

There are pressures on the production of beef and the provision of groundwater as a result of habitat change. Groundwater is also under threat from pollution. Soil formation and composition and groundwater recharge, the regulating services that support these provisioning services, are also under pressure.

5.9.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

Increased abstraction from and pollution of the Orange River upstream in South Africa represents a limited threat to downstream uses and related ecosystem functions in Namibia. Continued expansion of irrigation along the river in Namibia (e.g. for vineyards) is also adding to these pressures. Further research is needed to understand whether the ecosystem zone can continue to mediate the abstraction and pollution of water in the Orange River.

Expansion of urban areas and increasing industrialisation

There are no significant threats from industrialisation or urbanisation in this ecosystem zone.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the ecosystem zone to be used for agriculture.

Rapid expansion of mining and prospecting

There are possible threats from the potentially rapid expansion of mining and prospecting in this ecosystem zone.

Unsustainable land management practices

Overgrazing is thought to be causing land degradation in this ecosystem zone.

Uncontrolled bush fires

Uncontrolled bush fires are not a threat in this ecosystem zone.

Alien invasive species

Prosopis in the riverbeds is reducing flows and possibly surface runoff into dams, but it is not yet affecting the delivery of the service.

Illegal harvesting and trade of wildlife and forest and plant resources

There may be some poaching occurring in the northern strip, but this is discussed in the Western Highlands section.

Human-wildlife conflict

There is some human-wildlife conflict in the zone with predators, but these are often tolerated for their tourism value.

5.9.3.3 Economic importance (current and potential)

Recreational tourism (including hunting) is an important economic activity in the ecosystem zone, along with the commercial production of livestock, crops and wild plants such as truffles.

5.9.3.4 Affected population (size and socio-economic characteristics)

The provision of water is relevant to significant populations, particularly because of its relative scarcity. As livestock and crop farming are commercialised, they are also important to relatively large populations.

5.9.3.5 Availability of data

The services with the greatest availability of data are likely to be provisioning services (such as livestock) that are marketed, as these transactions are registered and consequently the estimation of their flows is relatively simple. The numbers of tourists staying in different types of accommodation should be available from the operators of lodges and campsites. Research

conducted in the zone should be able to provide some data on regulation and maintenance services, while estimates of water flows should be available.

5.9.4 References

Auala, H., Cloete, C., Gottlieb,T., Haimbili, E., Hembapu, N.m, Kabajani, M., Ndjamba, J.m, Shekunyenge, A., Shipani, H. & Shuuya, T. 2012. An analysis of the environmental and socio-economic impacts of Prosopis in the Auob and Nossob Basins, Namibia. Unpublished report, Summer Land Care Programme, Desert Research Foundation of Namibia, Windhoek.

Barnard, P. (ed.) 1998. Biological diversity in Namibia: a country study. Windhoek: Namibian national Biodiversity Task Force.

Biggs, D. 2009. Water use at Noordoewer / Vioolsdrif and Hardap Irrigation Schemes using different crops and irrigation methods. Ephemeral Rivers Project, Desert Research Foundation of Namibia, Windhoek.

Brown, C.J. 2006. Historic distribution of large mammals in the Greater Fish River Canyon Complex, southern Namibia, and recommendations for re-introductions. Unpublished report, Namibia Nature Foundation, Windhoek.

Christelis, G. and Struckmeier, W. (eds.) 2001. Groundwater in Namibia – an explanation to the hydrogeological map. Ministry of Agriculture, Water and Rural Development and the Ministry of Mines and Energy.

Dirkx, E., Hager, C., Tadross, M., Bethune, S. And Curtis, B. 2008. Climate change vulnerability and adaptation assessment. Desert Research Foundation of Namibia and the Climate Systems Analysis Group. Unpublished report for the Ministry of Environment and Tourism.

Domptail,S.E, Dreber,N., Falk,T., Gibreel,T., Kirk,M., Limpricht,C., Naumann,C., Prediger,S., Wesuls,D. 2010.An ecological-economic analysis of the Karoo in southern Namibia. In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Dreber N and Haarmeyer DH. 2010. Niko North (S08). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Dreber N and Haarmeyer DH. 2010. Niko South (S09). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Dreber N and Haarmeyer DH. 2010. Gellap Ost (S10). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Dreber N and Haarmeyer DH. 2010. Nabaos (S11). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Irish, J. 2009. Biological characterisation of the Orange-Fish River Basin, Namibia. Report produced for the Ephemeral River Basins in Southern Africa (ERB) Project, Desert Research Foundation of Namibia, Windhoek.

Joubert, E. & Mostert, P.K.N. 1975. Distribution patterns and status of some mammals in South West Africa. Madoqua 9: 5-44.

Jürgens N, Klanzer S.-E and Haarmeyer DH. 2010. Karios (S12). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

MAWF. 2011. Environmental and social impact assessment for the Neckartal Dam Project. Unpublished report by Knight Piesold (Pty) Ltd Consulting Engineers and Environmental Scientists.

Mendelsohn, J. 2006. Farming systems in Namibia. Namibia National Farmers Union.

Shortridge, G.C. 1934. The mammals of South West Africa. Vols 1 & 2. London: Heinemann.

Smit, P. 2005. Geo-ecology and environmental change: an applied approach to manage Prosopis-invaded landscapes in Namibia. Ph.D thesis, University of Namibia.

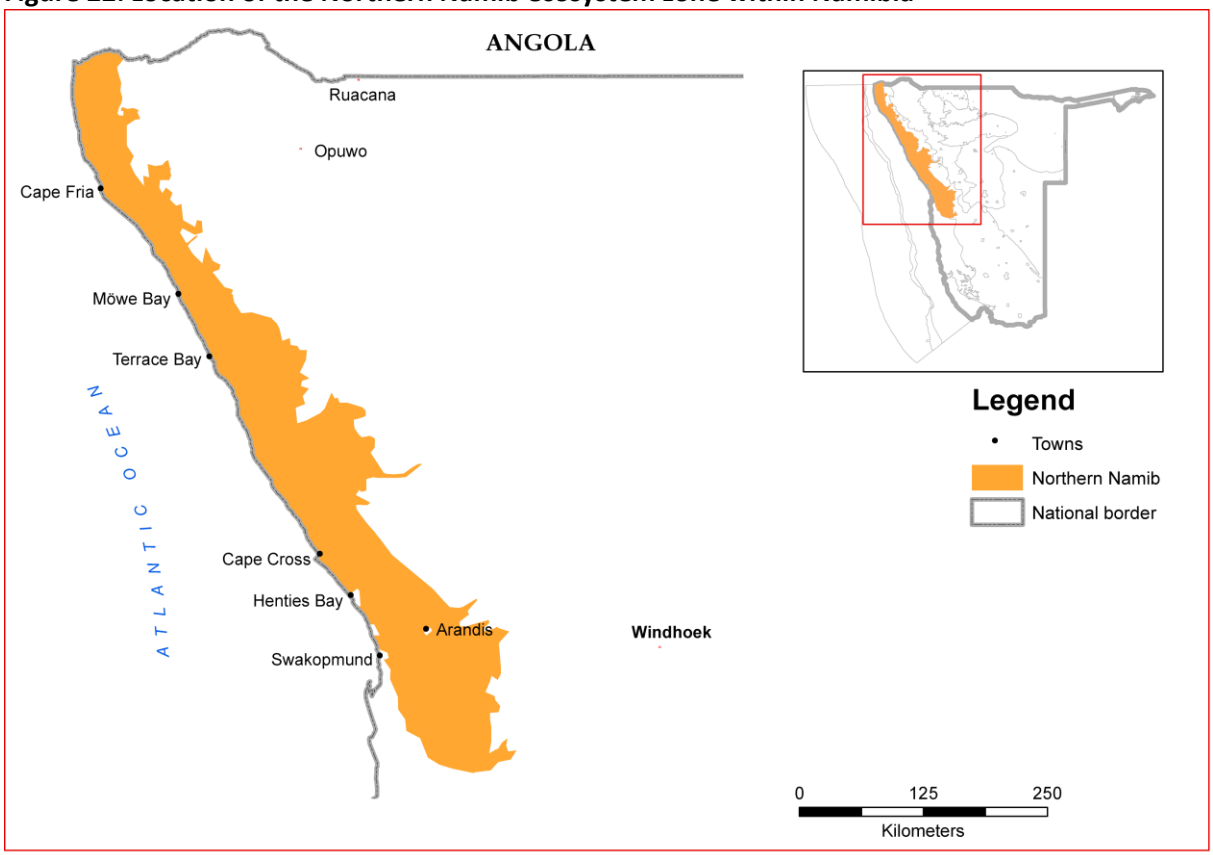
5.10 Northern Namib

5.10.1 Description and assessment of ecosystem zone

5.10.1.1 Main attributes and ecological processes

The Namib Desert extends along the entire coast of Namibia, and the northern section, mapped in Figure 22, covers approximately 53,000 km^2. This zone mostly comprises open gravelly and rocky plains and mountains, with small patches of dunes. This coastal plain extends to about 120 km inland in some areas (e.g. east of Swakopmund) but is very narrow elsewhere, and gradually gets narrower northwards (it is only about 60 km wide at Cape Fria). It is cut by the paths of westward-flowing ephemeral rivers which have their catchments in the comparatively higher rainfall areas to the east. The land rises steadily from sea level to between 500 and 1,000 m on the inland edge of the zone.

Figure 22: Location of the Northern Namib ecosystem zone within Namibia



The southern section of the Northern Namib (also called the 'central Namib'), extending up to about Cape Cross, is a relatively flat, sandless plain with isolated inselbergs. Within about 60 km of the coast, corresponding to the regular occurrence of fog, the soil has a gypsum crust below which is gypsum-cemented gravel and sand. This gives the soil a highly porous structure, and provides the substrate for extensive lichen fields with very little other vegetation. Further inland the substrate is more calcareous, with hard calcrete nodules formed from precipitation of calcium carbonate in the soil.

The northern section is topographically more diverse. A thin dune field stretches from Torra Bay north to the Hoarusib River, and reaches approximately 40 km inland, while a larger dune field

surrounds the mouth of the Kunene River in the very north. Plains and undulating areas with rocky ground occur north of the Ugab River, with the gravelly and rocky substrate derived from basalts and granites exposed on higher ground inland.

Occasional stretches of the coast, mainly in the north, have salt flats immediately inland. These comprise of low-lying land with a thin crust of crystalline salt and sand overlying saturated, muddy ground. Also lining the coast are stretches with low dune hummocks associated with shrubs in a narrow zone adjacent to the beach, where sand blown off the beaches accumulates around the plants.

The central Namib plains are interrupted by infrequent ridges of marble and dolerite, and there are also granite outcrops such as Vogelfederberg and Blutkoppie.

Many rivers drain off the Western Highlands that lie to the east of the Namib coastal plain, and the inland areas beyond them. The southern limit of this zone is demarcated by the Kuiseb River (described as part of the Namib Sand Sea); moving northwards are the Swakop, Omaruru, Ugab, Huab, Koigab, Uniab, Hoanib, Hoarusib and Khumib Rivers. Their flows are sporadic, sometimes with nothing at all for a year or more, but also punctuated with occasionally violent and destructive floods that are much more powerful than the average. Many flows do not reach the ocean because they do not have the volume, and the Hoanib and Uniab are blocked by sand dunes, so their sediments and debris are deposited in the river beds, contributing nutrients that support the vegetation growth along the river courses. Groundwater and the relatively richer river-bed soils support a thin line of trees, shrubs and occasional patches of grasses, which form linear oases crossing the barren desert. Surface water can last for several months, and is also permanently available at occasional springs and ravines.

Rainfall is at its lowest in Namibia along the Namib coast, where the average is less than 20 mm, and some years can pass with no rainfall at all. There is a steep gradient of increasing rainfall moving eastwards, with the inland limit of this zone receiving about 125 mm on average. Rain usually falls in intense summer thunderstorms, and tends to be patchily distributed. Such storms lead to the phenomenon of 'flash floods', where a small catchment may receive a large amount of rain in a short time, and quick runoff from the hard substrate produces a large volume of water.

The central Namib coastal area (surrounding Walvis Bay) receives more frequent fogs than other areas to the north and south, with about 146 fog-days per year at Walvis Bay[42]. Fog water precipitates on ground features and contributes a critical source of water for relatively smaller animals and plants, and importantly for the lichen fields.

Winds are generally strongest at the coast, driven mainly by the presence of the offshore anticyclone that is strongest in summer and drives southerly and westerly winds onshore. Occasional winds from inland during late summer and winter can be very intense; these east winds are warm and dry.

This very arid zone has little vegetation. The plains of the central Namib (most concentrated between the Kuiseb and Omaruru Rivers) are dotted with low shrubs (e.g. *Arthraerua leubnitziae,*

[42] Robertson et al 2012

Salsola spp, *Zygophyllum stapffii*), and the main feature in this area is the lichen which grows abundantly on the surface soil and stones. Along the coastline there are patches with a narrow zone of low hummocks, where sand is trapped around shrubs. In the northern areas, on more gravelly and rocky substrates, there are also low shrubs and, in certain areas, patches of *Welwitschia* plants. Large euphorbia plants, mainly *Euphorbia damarana*, dominate areas of rocky substrate. Sloping ground, ridges and low mountains tend to catch more moisture from the fog and therefore host more plants and greater diversity.

The river beds host tall trees such as ana tree (*Faidherbia albida*), camelthorn (*Acacia erioloba*), and smaller tamarisk (*Tamarix usneoides*) and wild ebony (*Euclea pseudebenus*). There are also dense bushes of *Salvadora persica*, and alien invasive plants such as wild tobacco (*Nicotiana* sp) and *Prosopis* spp. are common in certain areas.

The Namib has a rich invertebrate fauna, with particularly high diversity in the solifuges and scorpions. Also, the area is known for unusually high diversity of *Pachydactylus* lizards (small geckos). The large wildlife fauna comprises the typical desert species: springbok, oryx, mountain zebra and ostrich. In the Skeleton Coast Park and adjacent conservancies there are also significant numbers of giraffe, black rhino and elephant. Elephants prefer to stay in the river beds where there is adequate forage but occasionally they must also move over the plains between rivers. Predators such as lion, cheetah, leopard and both spotted and brown hyenas also frequent the area.

5.10.1.2 Human activity and population

The largest town that falls completely within the Northern Namib is Arandis, with a population of approximately 5,200. It was established for the workers of the world's largest open-pit uranium mine (Rössing Uranium Mine) which is 15 km from the town. Its population has grown by about 31% since 2001. Swakopmund and Henties Bay lie partially within zone, but are described in the Coastal and Near-Shore section (see Section 5.12.4).

The rest of the zone is very sparsely populated; it is estimated that 1,700 people live in its rural areas, an increase on the 1,100 estimated in 2001. Most of the resident population are Topnaar people living along the Kuiseb River. There are some MET and NWR staff at stations in the Parks and small numbers of people live in the communal areas to the east of the Parks in the north. It is the second least densely populated ecosystem zone in rural terms, at 0.03 people per km^2. The ecosystem zone falls within the Kunene and Erongo regions, but given the low rural populations socio-economic characteristics are not presented.

The Northern Namib encompasses the entirety of the Skeleton Coast and Dorob National Parks, as well as the Skeleton Coast Tourism Concession and part of the Palmwag Tourism Concession. Parts of 10 conservancies that border the National Parks and Tourism concessions fall within the zone, as well as five Community Forests that correspond to these Conservancies. The term 'Forest' here seems inappropriate but refers to any vegetation (grass pastures, trees in river beds, and shrubs such as *Commiphora*) that is managed by local communities, in the same way that wildlife is managed by community conservancies.

5.10.1.3 Pressures and drivers of change

Table 44: Broad drivers of change and ecosystem-specific pressures in the Northern Namib ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Off-road driving; mining; prospecting; quarrying (especially on inselbergs); overgrazing
Exploitation	Abstraction of groundwater; increases in livestock numbers; harvesting of wildlife
Pollution	Risk of pollution from mining
Invasive species	Proliferation in river beds, by species such as *Nicotiana* and *Prosopis*
Climate change	Possible increased aridity
Illegal use	Some poaching in the northern areas, and informal gemstone mining

Table 44 relates the six broad categories of drivers of change to specific pressures within the Northern Namib ecosystem zone. Almost the entire Northern Namib is State Protected or conservancy land, and consequently land use management is geared towards conservation. The major driver of change in the zone is the exploitation of groundwater, which has seen a significant increase in recent years.

Overgrazing has occurred in the communal areas of the zone, immediately east of the Parks; this has in turn reduced carrying capacities of the pastures. Off-road driving is also a pressure; it not only inflicts aesthetic damage to the landscapes, but also physically destroys lichens and the crust of gypsum soils. This and the effects of littering from associated human activities are discussed in the Coastal and Near-Shore ecosystem zone in Section 5.12.4.

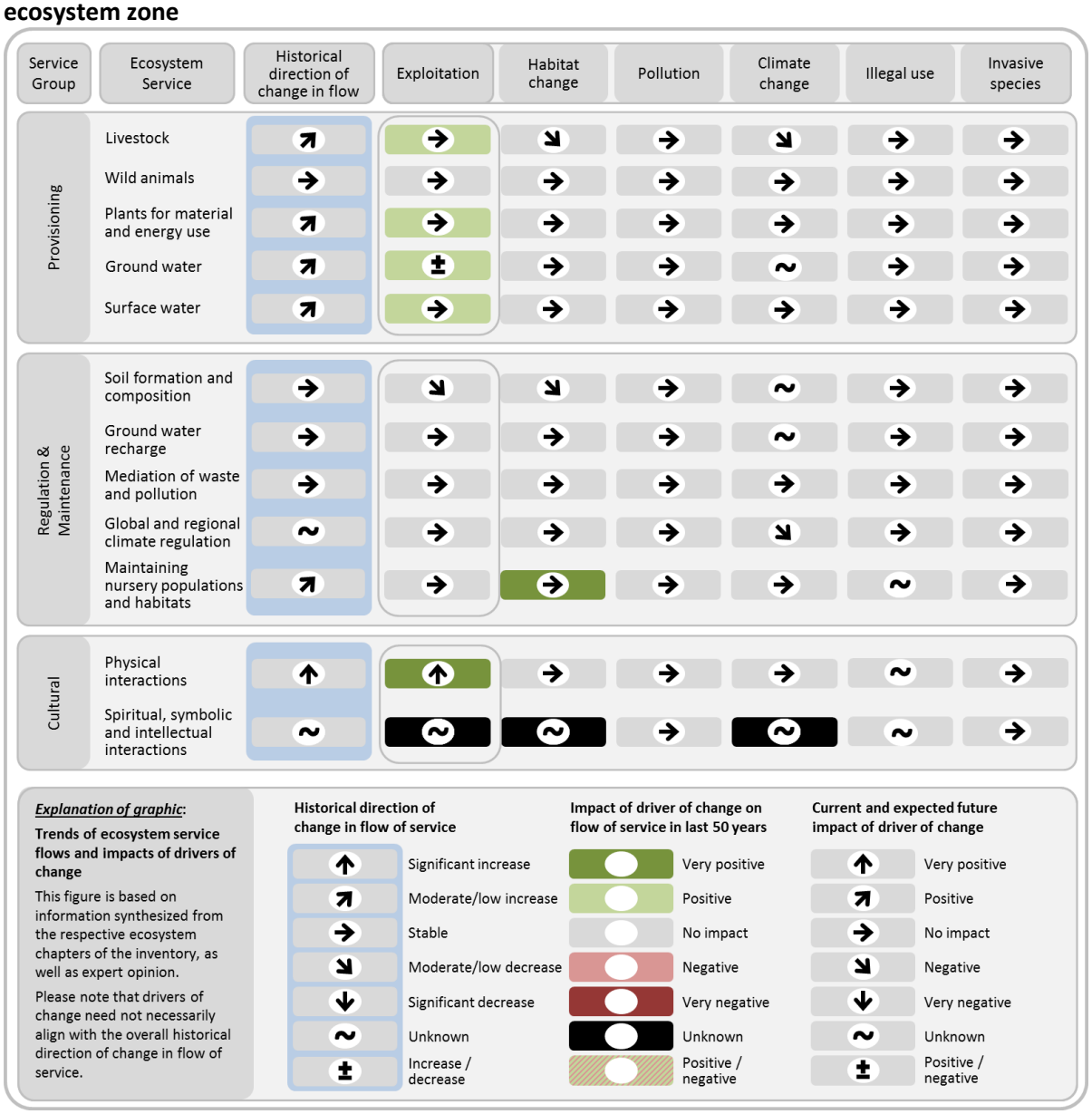
Mining and geological exploration have significant impacts in the Namib, from the footprint of the mines themselves, the associated infrastructure, water demand and access roads that they initiate, and the often more damaging activities of prospecting. There is some risk of pollution from mining via the radioactive materials being extracted at uranium mines and the chemicals used to extract them. Diamond mining along the Skeleton Coast has destroyed some beach and onshore habitats.

More minor pressures relate to poaching within the communal lands and the parks. Climate change could increase the aridity of the zone, but its precise effects are highly uncertain. There is no indication of how fog will be impacted by climate change; this will have an important bearing on the lichen, plant and invertebrate fauna of the Namib, with ramifications for the wider ecosystem.

5.10.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Northern Namib ecosystem zone. Figure 23 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 23: Overview of flows of services and impacts from drivers of change in the Northern Namib ecosystem zone



5.10.2.1 Provisioning

Table 45 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Northern Namib (and which are comparable to those classes specified in Figure 23). It also provides broad estimates of the scale of the population affected by the service and the type of economic value associated with it.

Table 45: Overview of provisioning services in the Northern Namib ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Reared animals and their outputs	Limited production of meat and dairy from livestock (goats and cattle)	Local	Consumptive use
Reared animals and their outputs	Livestock as capital (cattle)	Local	Consumptive use
Wild animals and their outputs	Meat from wildlife	Local	Consumptive use
Groundwater for drinking	Drinking water pumped from aquifers (e.g. Omdel and some of the ephemeral rivers)	Regional	Consumptive use
Fibres and other materials from plants, algae and animals for direct use or processing	INPs	International	Consumptive use
Surface water for non-drinking purposes	Water for wildlife and livestock	Local	Consumptive use
Groundwater for non-drinking purposes	Domestic water for urban users (Henties Bay, Swakopmund, Wlotzkasbaken) and industry from Omdel	Regional	Consumptive use
Groundwater for non-drinking purposes	Water for wildlife and livestock	Local	Consumptive use
Plant-based resources	Fuel wood from trees in river beds	Local	Consumptive use

Description

The small rural population in Northern Namib (in communal land alongside the eastern boundary of the Parks) farm cattle and goats and hunt wildlife for food. The services relating to livestock are not a permanent feature of the zone, however, but rather occasional following incidents of rain. Drinking water is generally pumped from aquifers (e.g. at Omdel, then held in the dam, and in some of the ephemeral rivers), and these are also the primary source of water for domestic and industrial use, and for wildlife and livestock. Water from Omdel is also pumped to Henties Bay, Swakopmund, Arandis and to the Rössing Uranium Mine. The Omdel supply is not sufficient to meet the needs of new mines in the zone, and consequently a desalination plant has been established at Wlotzkasbaken, and another near Swakopmund is in the planning phase. Provisioning services derived from natural materials are very small; they relate to wood being harvested for fuel in the river beds and fodder for the small amount of livestock in the zone.

Affected population

The relevant population for the provisioning services relating to nutrition, materials and energy is mostly local, as they are generally used at the point of extraction or harvesting. Water from Omdel is also relevant to regional populations as it is pumped to Swakopmund and Henties Bay for use. The few cattle kept as capital are relevant to national populations as the owners often live outside of the zone.

Change in flow over past 50 years

The flows of all provisioning services in this zone are estimated to have increased in recent decades, largely as a result of increased human exploitation. The services demonstrating the most significant upward trends are those related to water provision to nearby towns, the populations of which are growing rapidly.

Pressures and expected impacts on flow of service

The exploitation of provisioning services used at the local level is expected to stabilise or possibly decline as rural populations in the ecosystem zone decrease. The trend in the exploitation of water to be pumped to coastal towns is not clear; the new desalination plant may reduce demand somewhat, and there is a chance the aquifer itself may have been overexploited, but urban populations are set to keep growing.

Climate change could reduce the availability of grazing and browse for wildlife and the small numbers of livestock. Its impact on the provision of drinking and non-drinking water from aquifers is unclear.

5.10.2.2 Regulation and maintenance

Table 46 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Northern Namib.

Table 46: Overview of regulation and maintenance services in the Northern Namib ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect use
Maintaining nursery populations and habitats	Habitat for desert lion/ elephant etc.	International	Indirect use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure in the river beds	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Very limited carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Limited role in maintenance of regional precipitation/temperature patterns	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances is generated largely at the ecosystem level by the absorption of pollutants and the dilution of gases into the atmosphere. The mediation of flows relates to both liquids (groundwater recharge) and gases (through vegetation enabling air ventilation).

Services in the maintenance of physical, chemical and biological conditions are more broadly defined. In this hyper-arid system, soil formation, nutrient storage and climate regulation (through carbon sequestration) are negligible and/or happen extremely slowly, punctuated by short periods after rains when there is moisture in the system. These processes are more pronounced and ongoing in dry river beds, but overall their contribution is very small. The river beds in the ecosystem provide a crucial habitat for large wildlife species and other vertebrate and invertebrate taxa that are important in nutrient cycling. The gypsum substrates are host to a diverse assemblage of lichens which in turn provide habitat for invertebrates.

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of liquid and gaseous flows. The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level. The habitat the dry river beds provide is relevant internationally to the extent it supports internationally recognised and endangered species. Carbon sequestration is probably so small that it is insignificant in this ecosystem; if any, its effect is global.

Change in flow over past 50 years

The only regulation and maintenance service to have demonstrated a distinct change in flow is that relating to the habitat for wildlife in the dry riverbeds, as the designation of conservancies has helped to rebuild populations of particular species. The other services are so limited that any changes in their flow would be insignificant.

Pressures and expected impacts on flow of service

Limited change in flow in the regulation and maintenance services is expected.

5.10.2.3 Cultural

Table 47 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Northern Namib.

Table 47: Overview of cultural services in the Northern Namib ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Landscape appreciation; some wildlife viewing	International	Non-consumptive use
Scientific	Research on desert lion; Gobabeb	International	Non-consumptive use
Heritage, cultural	Cultural ties to landscape by indigenous peoples	Local	Non-consumptive use; bequest; existence
Aesthetic	Representations of Skeleton Coast	International	Non-consumptive use
Symbolic	Representations of Skeleton Coast	International	Non-consumptive use
Existence	Relating to landscapes, wildlife, remote wilderness areas	International	Existence
Bequest	Relating to landscapes, wildlife, remote wilderness areas	International	Bequest

Description

Non-consumptive recreational tourism in the ecosystem is primarily based around landscape appreciation and wildlife viewing. Wildlife in the Northern Namib and neighbouring ecosystem zones gives rise to a range of research, particularly with regard to lion, elephant and giraffe that inhabit the dry river beds running towards the Namibian coast.

The landscapes also give rise to aesthetic and symbolic services, as the Skeleton Coast is often presented in representations of Namibia. It encompasses the remote rugged areas of north-western Namibia, which are not only important for tourism but also have cultural values to indigenous peoples such as the ovaHimba and others. Existence and bequest services are likely to be derived from the wildlife, landscapes and livelihoods and ways of life.

Affected population

Tourists to the zone are primarily international visitors; scientific, aesthetic, symbolic and the existence and bequest services relating to wildlife, landscapes and ways of life are also relevant to international populations. The heritage and cultural values are relevant locally.

Change in flow over past 50 years

Recreational tourism has increased significantly in recent decades; scientific services are also thought to have increased. The flow of services relating to other cultural services is not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone; this is likely to be as a result of a combination of improved access to some areas and the continued development of facilities. Poaching could represent a threat in the longer term to recreational tourism, but at its current level it is not thought to be of significance. The effects of pressures on other cultural services are generally poorly understood.

5.10.2.4 Interactions between ecosystem services

The communal areas have been subject to overgrazing, which has in turn led to soil degradation and reduced carrying capacity of rangelands. This has been exacerbated by the very marginal nature of these lands for the purpose of farming or keeping livestock. There are also important interaction with neighbouring ecosystem zones such as the northern strip of the Nama Karoo and the Western Highlands, as these zones link up for critical wildlife movement corridors, and also the Coastal and Near-Shore zone.

5.10.3 Criteria for prioritisation of ecosystem services

5.10.3.1 Current and future expected impacts on the flow of the service

There are pressures on rangelands and the production of meat from livestock, but these are relatively limited activities.

5.10.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

There are threats from unsustainable water use in this ecosystem arising predominantly from mining. Although desalination facilities have been established, with more planned, they have not taken over (as intended) as the main supply of water for mines. The growth of urban populations and industries in coastal towns is also increasing demand, which may be resolved through desalination. Again, that important supplementation of water supplies by desalination has not yet occurred.

Expansion of urban areas and increasing industrialisation

The central Namib is the most active developing industrial zone in the country. Service industries for mines and quarries, development and proposals for industrial zones, additional ports and expansion of Walvis Bay port facilities, tourism developments and conferencing facilities all contribute to this growth. This expansion and potential pollution pose threats to biodiversity (e.g. lichen fields, Damara tern breeding sites, range-restricted invertebrate and reptile species) and to services such as water provision and the aesthetic appeal of the Namib coast.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, given that the future trend of coastal fog is so unknown. Marine changes in the Benguela, such as sea warming, could have far-reaching effects on rain and fog in the Namib, with major consequences for biodiversity and ecosystem services.

Rapid expansion of mining and prospecting

Mining is occurring in the zone, and there are risks of pollution and contamination, as well as damage to landscapes. Extinction of range-restricted invertebrates from mining is likely, with unknown consequences for ecosystem services. The extent of mining and prospecting in this ecosystem is likely to grow and represents one of the most important threats to biodiversity and ecosystem services.

Unsustainable land management practices

Overgrazing is thought to be causing land degradation in the eastern parts of this ecosystem where there is communal rangeland.

Uncontrolled bush fires

Uncontrolled bush fires are not a threat in this ecosystem zone.

Alien invasive species

Alien invasive weeds (namely *Nicotiana* and *Datura* species), and *Prosopis* are common in many river beds and probably have a negative impact on groundwater and biodiversity.

Illegal harvesting and trade of wildlife and forest and plant resources

There is poaching occurring in the area, which has usually been associated with geological exploration and mining. A concern is the impact of poaching of iconic species such as rhinos, under the guise of prospecting in EPLs taken up by foreign interests.

Human-wildlife conflict

There is some human-wildlife conflict in the zone with predators, but this is limited by the general lack of human populations.

5.10.3.3 Economic importance (current and potential)

Recreational tourism is an important economic activity in the ecosystem, particularly for the conservancies to the east of the parks. There is significant growth potential if the Skeleton Coast National Park is developed. The Gobabeb Research and Training Centre conducts research throughout this ecosystem and the Namib Sand Sea.

5.10.3.4 Affected population (size and socio-economic characteristics)

Recreational tourism is probably the most relevant service to people living in the zone as it supports much of the formal employment there. Cultural services relating to rural populations and their ways of life may also be prioritised under this criterion.

5.10.3.5 Availability of data

The large number of environmental impact assessments and the Uranium Rush strategic environmental assessment all provide potential data sources for assessing potential flows of ecosystem services. Gobabeb has collected significant data on a wide variety of environmental

indicators since its inception. The numbers of (formal) tourists staying in different types of accommodation should be available from the operators of lodges and campsites.

5.10.4 References

Eckart, F.D. and Spiro, B. 1999. The origin of sulphur in gypsum and dissolved sulphate in the Central Namib Desert, Namibia. Sedimentary Geology 123: 255-273.

EEAN. 2008. Rössing biodiversity assessment. Unpublished report compiled by Environmental Evaluation Associates of Namibia, for Rössing Uranium (Ltd).

Jacobson, P.K., K.M.Jacobson and M.K.Seely. 1995. Ephemeral rivers and their catchments: Sustaining people and development in western Namibia. Desert Research Foundation of Namibia, Windhoek.

Jürgens N and Haarmeyer DH. 2010. Wlotzkasbaken (S16). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Jürgens N and Haarmeyer DH. 2010. Kleinberg (S34). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Jürgens N and Haarmeyer DH. 2010. Ganab (S36). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

LAC 2009. Striking a better balance: an investigation of mining practices in Namibia's Protected Areas. Legal Assistance Centre and Mills international Human Rights Clinic, Stanford law School.

Lalley, J.S. 2005. Lichen-dominated soil crusts in the hyper-arid Namib Desert: anthropogenic impacts and conservation implications. PhD thesis, University of Oxford, UK.

Lalley, J.S. and Viles, H. 2006. Do vehicle track disturbances affect the productivity of soil-growing lichens in a fog desert? Functional Ecology 20(3): 548-556.

Lalley, J.S., Viles, H.A., Henschel, J.R. and Lalley, V. 2006. Lichen-dominated soil crusts as arthropod habitat in warm deserts. Journal of Arid Environments 67 (4): 579-593.

MET. 2015. Climate change vulnerability and adaptation assessment. Ministry of Environment and Tourism.

MME. 2010. Strategic environmental assessment of the central Namib uranium rush. Prepared by Southern African Institute for Environmental Assessment, for the Ministry of Mines and Energy.

NACSO. 2010. Assessment of climate change impacts and adaptation options for Namibia's CBNRM programme in Kunene and Caprivi. Unpublished report compiled by Southern African Institute for Environmental Assessment.

Robertson, T. Jarvis, A., Mendelsohn J., Swart, R. 2012. Namibia's coast – ocean riches and desert treasures. Research and Information Services of Namibia, Windhoek.

Seely, M. and Pallett, J. 2008. Namib – secrets of a desert uncovered. Venture Publications, Windhoek.

Turpie J, Midgley G, Brown C, Barnes J, Pallett J, Desmet P, Tarr J, Tarr P. 2010. Climate change vulnerability and adaptation assessment for Namibia's biodiversity and protected area system. Final Report to Ministry of Environment and Tourism, by Anchor Environmental Consultants, Namibia Nature Foundation and Southern African Institute for Environmental Assessment.

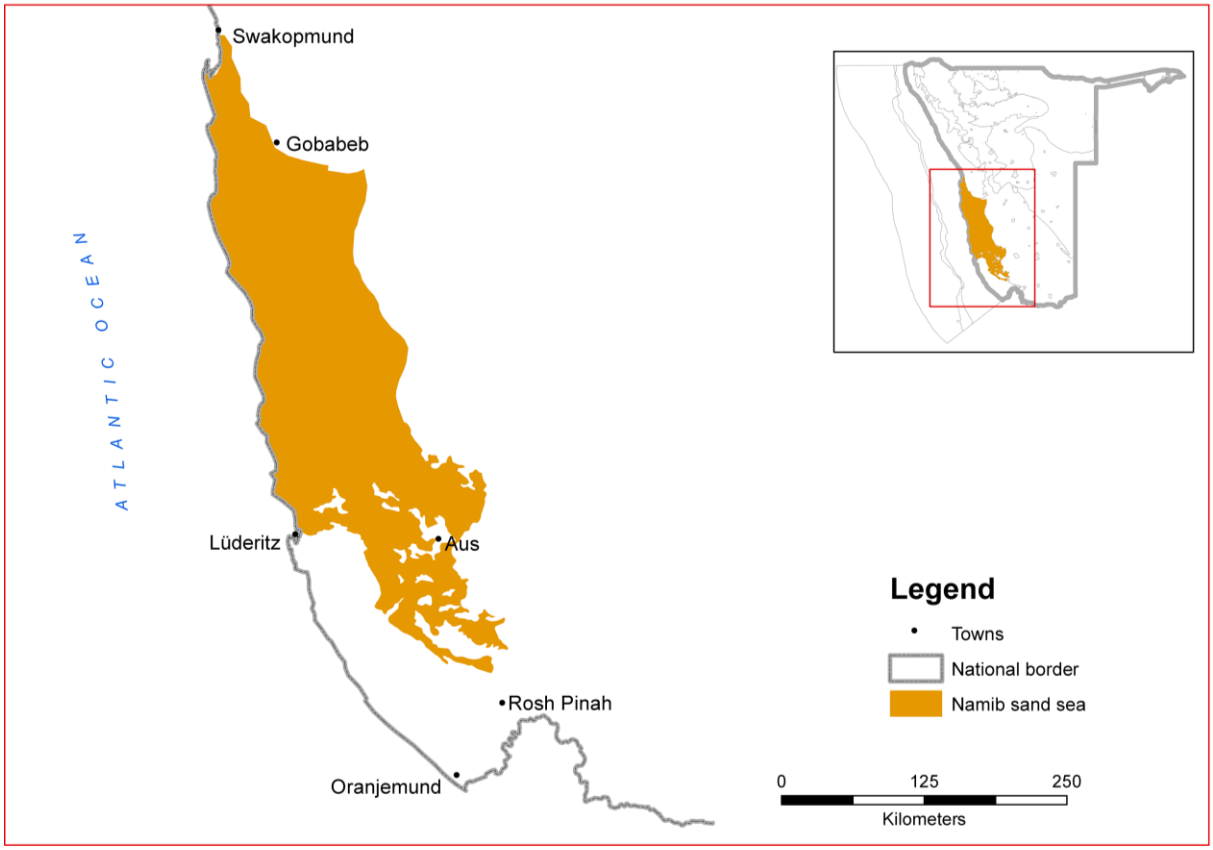
5.11 Namib Sand Sea

5.11.1 Description and assessment of ecosystem zone

5.11.1.1 Main attributes and ecological processes

The main body of the Namib Sand Sea lies between Lüderitz and Walvis Bay, extending from the coast to about 100-120 km inland as illustrated in Figure 24. The land rises gradually from sea level to about 1,000 m altitude where it meets the base of the western escarpment. Sand dunes also get higher further east, and then rapidly give way to low sandy undulations and open sandy plains interspersed with inselbergs in the area informally known as the 'pro-Namib'. South of Aus this zone extends along the eastern edge of the Succulent Karoo, and sand dunes are also not well developed in this area. The Namib Sand Sea covers approximately 47,000 km^2.

Figure 24: Location of the Namib Sand Sea ecosystem zone within Namibia



The Sand Sea is aptly named as it is mostly covered in sand dunes of different types, determined by the force and directionality of winds, available sand supply, and the tendency of plants to establish where sand movement is little enough for them to do so. A great diversity of dune forms exists, but the overall pattern is as follows: those nearer the coast tend to be more mobile and barchan-shaped; those in the central parts form long linear shapes trending mainly north-south; and in the east they tend to form star shapes and be more vegetated. Valleys separating the dunes have a sandy-gravelly substrate, and support annual grasses. There is also a gradient in colour of the sand, from white/pale grey at the coast, to more orange and red further inland. This is due to the coating of iron oxide around the individual grains.

Near the coast and in the middle portion of the dune field, the dunes are mostly barren of vegetation except near the base, where the sandy substrate is stable enough to allow plants to establish. Just a few species of perennial grasses and succulent shrubs exist, and they have specialised adaptations for absorbing fog water. The spiny dune plant, !nara (*Acanthosicyos horridus*), which produces prolific melons, is found mainly in the western part of the dunes, and only in places where its deep tap root can access groundwater. Thus the greatest density of !naras is in the Kuiseb river delta. Towards the east the dunes host more grasses, and the plants cover more of the dunes, with only the dune crests being free of plants.

Wind is an important feature of the Namib. It determines the shape of the dunes and the rate of movement of the fine dune sand, which in turn influences plant growth. Fragments of vegetation and other organic matter are carried by wind onto the dunes, where they get embedded under the billowing sand and form pads of detritus, or swirl around loosely on the slopes. This makes up the food source for a wide diversity of beetles and other invertebrates.

Precipitation in the Sand Sea comes from two sources, fog and rain. Fog is generated along the coast so it is most frequent there and lasts longer during the day (e.g. average 140 days per year at Walvis Bay, 117 days per year at Lüderitz). It also penetrates inland, extending 60 km and more into the dunes and condensing on the surface and on plants, where it provides useful moisture to plants and small animals. Behavioural and physiological adaptations to using this water source are seen in, for example, fog-basking beetles and the unique ability of one dune succulent plant, *Trianthema hereroensis*, to absorb fog water through its leaves.

Rain comes only in occasional cloudbursts mainly in summer, and is much less than fog in the total volume of water supplied. There are opposing east-west gradients of rain and fog: average annual rainfall drops from about 100 mm at the eastern edge of the Sand Sea, to about 20 mm at the coast, while fog precipitation drops from the coast heading inland. A belt in the centre receives little from both sources, and experiences the greatest water stress.

There are only two places in the Sand Sea where surface water is found, and this is only on very rare occasions. Rainfall in the Naukluft Mountains drains into the Tsondab and Tsauchab Rivers, which flow a short distance into the dune field and end in pans, namely the Tsondabvlei and Sossusvlei. Both of these rivers used to extend further west than at present, and in the geological past they carried more water, enough to sustain the trees that are now only skeletons in pans such as the famous Dead Vlei. The valley of the Tsondab River, and the end vlei, support stands of Acacia trees in which lappet-faced vultures rest and breed.

The northern boundary of the Sand Sea is demarcated by the Kuiseb River. The river carries water only sporadically (about six years out of every ten at Gobabeb) and serves to flush downstream any dune sand that has encroached into the valley. Most importantly, the ephemeral river has an alluvial aquifer and this groundwater supports tall trees and riverine vegetation along the river course. This makes the river a linear oasis through the hyper-arid surroundings, providing shade and shelter, occasional pools of water, and plant food.

Fine-grained sand is an unusual substrate, and factors such as degree of compaction, moisture content, vegetation and position on the dune relative to prevailing winds, creates a great variety of

dune habitats for animals. These animals (more than 300 species) exhibit many adaptations for sand-dwelling, and endemism is high at over 50%, reaching its highest level in the array of tenebrionid beetles in the dune field. Mammals and birds endemic to the Namib Sand Sea include Grant's golden mole (*Eremitalpa granti*) and the dune hairy-footed gerbil (*Gerbillurus tytonis*), dune lark (*Calendulauda erythrochlamys*) and Barlow's lark (*Calendulauda barlowi*), while reptiles endemic to the sand sea include shovel-snouted lizard (*Meroles anchietae*) and the wedge-snouted lizard (*Meroles cuneirostris*). Large animals such as oryx, springbok and ostrich tend to move around in response to the patchily distributed rain.

5.11.1.2 Human activity and population

There are no significant urban areas completely within the Namib Sand Sea; Walvis Bay lies between this zone and the Coastal zone, while Swakopmund also borders the Northern Namib as well as the Coastal zone. These towns are all discussed in the Coastal section (see Section 5.12.4).

The Namib Sand Sea is the least densely populated ecosystem zone described in this report, at less than 0.03 people per km^2; its population is estimated to have increased from 1,000 in 2001 to 1,300 in 2011, however. The general lack of human habitation is as a result of the difficulty of access into the dunes and the lack of surface water, although the indigenous Topnaar people live in the zone, with homesteads established on the banks of the Kuiseb River within about 80 km of Walvis Bay.

Much of the Namib Sand Sea lies within the Namib Naukluft Park, while the area south of Lüderitz falls within the Tsau //Khaeb National Park (formerly the Sperrgebiet). The Namib Sand Sea was proclaimed as a World Heritage Site in 2013, qualifying for this recognition on all four of the main categories for Outstanding Universal Value: natural beauty and aesthetic importance, geological processes, ecological processes and biological diversity.

5.11.1.3 Pressures and drivers of change

Table 48: Broad drivers of change and ecosystem-specific pressures in the Namib Sand Sea ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Farm dams upstream in Kuiseb River catchment
Exploitation	Harvesting of !nara melons; abstraction of groundwater
Pollution	No relevant pressures identified in this zone
Illegal use/Invasive species	*Prosopis* trees in the Kuiseb River bed
Climate change	Increased aridity
Illegal use	Illegal harvesting of !nara melons contributing to possible overexploitation

Table 48 relates the six broad categories of drivers of change to specific pressures within the Namib Sand Sea ecosystem zone. Due to the general inaccessibility of much of this area, as well as its location within a State Protected Area, there are generally few pressures, and no major ones. The exploitation of !nara melons may be at an unsustainable level, however, due to growing numbers of harvesters (both legal and illegal) and a growing use of unsustainable methods.

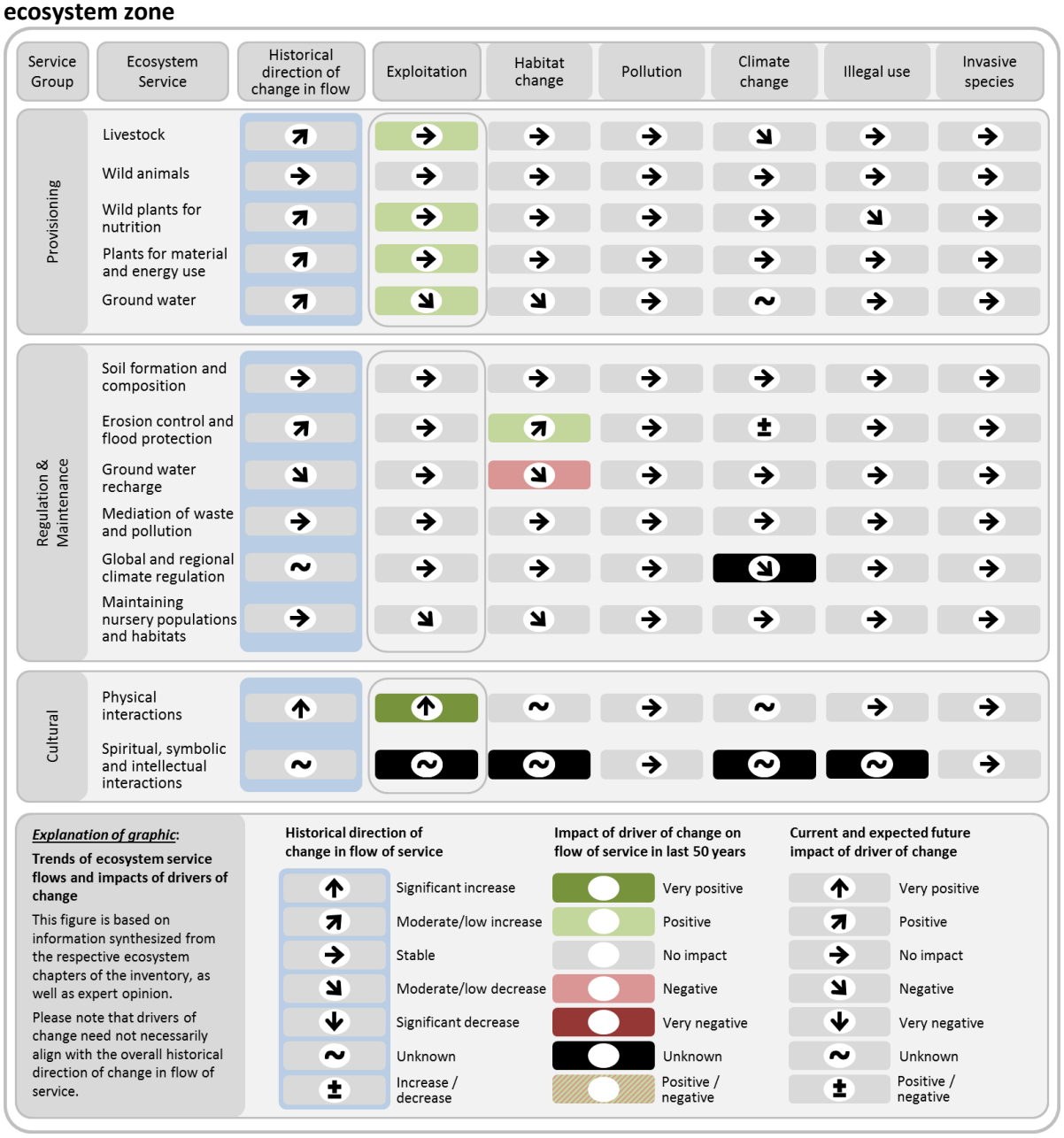
The number of livestock, particularly in the Kuiseb riverbed, has increased in recent years, prompting the concern that maturation of young trees is being prevented. There is abstraction of groundwater within the ecosystem which is also generally within recharge limits. However, the continued

exploitation of the Koichab aquifer will cause this fossil aquifer to dry up, while the impact of farm dams in the upstream catchment of the Kuiseb may be reducing flooding and consequently recharge of the Rooibank aquifer. Climate change could increase aridity in the ecosystem zone if rainfall decreases, but the effects on the fog regime are unknown. Impacts of climate change on river flows are also uncertain, since this is largely dependent on runoff in the upstream catchments. It is uncertain how this will be affected by the interactions of rainfall, vegetation cover and infiltration. A die-off of riverine vegetation was recorded in the 1980s from a drop in the water table.

5.11.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Namib Sand Sea ecosystem zone. Figure 25 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 25: Overview of flows of services and impacts from drivers of change in the Namib Sand Sea ecosystem zone



5.11.2.1 Provisioning

Table 49 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Namib Sand Sea (and which are comparable to those classes specified in Figure 25). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 49: Overview of provisioning services in the Namib Sand Sea ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Reared animals and their outputs	Limited production of meat and milk from livestock (mainly goats, some cattle)	Local	Consumptive use
Wild plants, algae and their outputs	!Nara melons as food	Local	Consumptive use
Wild animals and their outputs	Meat from wildlife	Local	Consumptive use
Groundwater for drinking	Drinking water for urban users in Walvis Bay (Kuiseb aquifer) and Lüderitz (Koichab aquifer)	Regional	Consumptive use
Groundwater for drinking	Drinking water for rural users from aquifers along the Kuiseb River and at Sesriem	Local	Consumptive use
Fibres and other materials from plants, algae and animals for direct use or processing	Hides from livestock; fodder (browse and fallen pods) in Kuiseb River bed	Local	Consumptive use
Groundwater for non-drinking purposes	Water for domestic urban use and industry, livestock and wildlife from aquifers	Regional	Consumptive use
Plant-based resources	Wood fuel	Local	Consumptive use

Description

Goats and small numbers of cattle are kept and used to produce some meat and dairy products by the indigenous Topnaar along the Kuiseb River. Other sources of food are small-scale hunting of wildlife for meat and the harvesting of !nara melons.

Drinking water for local rural populations is drawn from aquifers along the Kuiseb River and at Sesriem, and along with hand dug wells along the riverbed they also provide watering points for livestock. Water is also pumped from these Kuiseb aquifers to supply drinking, domestic, industrial and commercial water to Walvis Bay; similarly, water is drawn from boreholes at Koichab pan to supply Lüderitz. Other provisioning services in the zone include the harvesting of wood for fuel, fodder for livestock from browse and fallen pods in the Kuiseb River bed, and hides from livestock.

Affected population

Groundwater for drinking and non-drinking purposes is relevant to regional populations, as it is used to supply the towns of Walvis Bay and Lüderitz. All other services are generally used at the point of extraction or harvesting, and are consequently relevant at a local level.

Change in flow over past 50 years

The flows of all provisioning services in this zone are estimated to have increased in recent decades, generally as a result of increased human exploitation. The services demonstrating the most significant upward trends are those related to water provision to nearby towns, the populations of which are growing quite rapidly.

Pressures and expected impacts on flow of service

Rural populations are not expected to continue growing much further, and consequently the exploitation of livestock for meat, wood as fuel, hides from livestock and fodder is expected to stabilise. Climate change could reduce rainfall, leading to more intense droughts in the future. This may result in a drop in the water table and consequently a decline in riverine vegetation and the availability of fodder, reducing the capacity for livestock farming.

It is possible that !naras have been overexploited as a result of a combination of growing numbers of harvesters, and illegal (unsustainable) harvesting methods. This could decrease the availability of the resource in the future.

There are expected to be a number of negative pressures on the availability of groundwater. The Koichab Pan is a fossil aquifer and is only expected to last until 2022, so exploitation must decrease in the future. In addition, farm dams in the upstream catchment of the Kuiseb may reduce flooding and recharge of the Rooibank aquifer, and land degradation in the Kuiseb catchment could also reduce recharge of groundwater sources. The effect of climate change is unclear.

5.11.2.2 Regulation and maintenance

Table 50 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Namib Sand Sea.

Table 50: Overview of regulation and maintenance services in the Namib Sand Sea ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect use
Mass stabilisation and control of erosion rates	Flows in the Kuiseb River limit the expansion of the Sand Sea onto the Namib plains north of the Kuiseb	Regional	Indirect use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect use
Flood protection	Sands in the Kuiseb Delta absorb much of the flow of the river when it approaches the coast. This and a man-made dyke prevent flood waters from inundating Walvis Bay.	Regional	Indirect use
Weathering processes	Decomposition/mineralisation of dead organic material, nitrification	Regional	Indirect use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure. Very limited due to aridity.	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Very limited carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances is generated largely at the ecosystem level by the absorption of pollutants and the dilution of gases into the atmosphere. The mediation of flows happens at two levels: mass flows, whereby flows in the Kuiseb River limit the expansion of the Sand Sea onto the Namib plains north of the Kuiseb; and liquid flows, relating to groundwater recharge and flood protection (sands in the Kuiseb delta absorb much of the flow when it approaches the coast, preventing flood water from inundating Walvis Bay).

Relevant services in the maintenance of physical, chemical and biological conditions are more broadly defined. Soil formation and composition (through the decomposition/mineralisation of dead

organic material and nitrification, as well as the maintenance of the fertility of soils, nutrient storage and their soil structure) is extremely limited due to the dry conditions. Similarly, regulation of atmospheric composition through carbon sequestration is probably insignificant. Climate regulation (through the maintenance of regional precipitation/temperature patterns) is as important here as in other ecosystems. The Sand Sea is a critical habitat for a number of endemic species.

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of mass and liquid flows. The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level. The habitat the Sand Sea provides for certain endemic species is important internationally. The maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

Flows from groundwater recharge may have been reduced as a result of land degradation. The other services are not thought to have had any meaningful changes to their flow, probably as a result of limited human activity in the ecosystem.

Pressures and expected impacts on flow of service

Limited change in flow in the regulation and maintenance services is expected. Groundwater recharge is expected to continue declining as a result of land degradation. Climate change could also exacerbate the farming activities in the upper river catchments, intensifying land degradation, but how this will ultimately affect river flows is not known.

Micro and regional climate regulation could be negatively affected by climate change as a result of reduced rainfall, while less frequent flows in the Kuiseb River could threaten its service of limiting the expansion of the Sand Sea. Endemic species may be under threat from increased tourism and off-road driving.

5.11.2.3 Cultural

Table 51 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Namib Sand Sea.

Table 51: Overview of cultural services in the Namib Sand Sea ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Landscapes: dunes and wilderness characteristics	International	Non-consumptive use
Scientific	Gobabeb; Namib Sand Sea World Heritage Site	International	Non-consumptive use
Heritage, cultural	Sossusvlei; Topnaar; Namib Sand Sea World Heritage Site	International	Non-consumptive use; bequest; existence
Aesthetic	Representations of Namib Sand Sea	International	Non-consumptive use
Symbolic	Traditions and cultural cohesiveness based on the practices around !nara harvesting and processing	National	Non-consumptive use
Existence	Relating to Topnaar; Sand Sea itself	International	Existence
Bequest	Relating to Topnaar; Sand Sea itself	International	Bequest

Description

Tourism in the zone is heavily based around the desert landscapes, which includes Sossusvlei and Dead Vlei as major attractions. The NamibRand Nature Reserve, which is contiguous with the eastern boundary of the Namib-Naukluft Park, also draws tourists and has achieved recognition as an International Dark Sky Reserve.

There is significant scientific interest in the zone, which is represented by the Gobabeb Desert Research Training Centre. The recognition of the Sand Sea as a World Heritage Site recognises not only its scientific importance, but also its cultural importance. The Topnaar living within the zone are likely to also derive cultural services from the zone itself, as well as more specific symbolic services related to the practices surrounding !nara harvesting. There are also aesthetic, bequest and existence services.

Affected population

Tourists to the zone are primarily international visitors; the bequest, existence and scientific services, and those related to the World Heritage Site, are also relevant internationally. The services surrounding the harvesting of the !nara are relevant at a national level to the extent there may be some Topnaar extended families living outside the zone.

Change in flow over past 50 years

Recreational tourism has increased significantly in recent decades; scientific services are also thought to have increased. The service relating to the harvesting of !nara may be threatened by its

illegal and unsustainable use, while the flow of services relating to other cultural services is not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing in the zone; this is likely to be as a result of a combination of improved access to some areas and the continued development of facilities. Continued unsustainable or illegal harvesting of !nara is an ongoing threat to the cultural services surrounding their harvesting. The effects of pressures on other cultural services are generally poorly understood.

5.11.2.4 Interactions between ecosystem services

The main interactions are with coastal towns in the Coastal and Near-Shore zone, in particular through the supply of water and flood protection services.

5.11.3 Criteria for prioritisation of ecosystem services

5.11.3.1 Current and future expected impacts on the flow of the service

Groundwater is facing pressures from potential overexploitation upstream and potentially reduced rates of recharge.

5.11.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

The Koichab is a fossil aquifer and continued use will cause it to dry up, restricting supplies of water to Lüderitz.

Expansion of urban areas and increasing industrialisation

There are threats from industrialisation at the coastal towns of Walvis Bay and Lüderitz. The expansions are mainly to do with their functions as ports, but will also likely cause impacts such as pollution and disturbances to biodiversity on the land.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, particularly on fog.

Rapid expansion of mining and prospecting

Although mining is prohibited in the Namib Sand Sea World Heritage Site, there are still EPLs that are active within the demarcated area, and others continuing in the areas outside of the WHS.

Unsustainable land management practices

As much of the zone is under the management of protected areas, there are thought to be limited pressures from unsustainable land management practices. This is probably not the case along the Kuiseb River, where cattle, donkeys and goats are having a negative impact on riverine vegetation.

Uncontrolled bush fires

Uncontrolled bush fires are not a threat in this ecosystem zone.

Alien invasive species

Alien invasive species are mostly absent in this ecosystem, except for problematic *Nicotiana* and *Prosopis* along the river beds.

Illegal harvesting and trade of wildlife and forest and plant resources

The illegal harvesting of !naras could be contributing to their overexploitation and affect the cultural services the Topnaar derive from them.

Human-wildlife conflict

There is limited human-wildlife conflict in this ecosystem zone.

5.11.3.3 Economic importance (current and potential)

Recreational tourism is an important economic activity that has the potential to develop further.

5.11.3.4 Affected population (size and socio-economic characteristics)

Cultural services relating to the Topnaar and their ways of life may be prioritised under this criterion.

5.11.3.5 Availability of data

There is a significant amount of research in the zone, so there may be data on a range of services (for example through Gobabeb). The dossier compiled in support of the World Heritage Site nomination also has the potential to be an important source of data. Estimates of the numbers of (formal) tourists should visiting and staying in the ecosystem zone should be available.

5.11.4 References

Dausab, F., Francis, G., Jöhr, G., Kambatuku, J.R., Molapo, M., Shanyengana, S.E. and Swartz, S. 1994. Water usage patterns in the Kuiseb catchment area. Unpublished report, Summer Desertification Programme, Desert Research Foundation of Namibia.

Henschel, J.R., Dausab, R., Moser, P., Pallett, J. (eds.) 2004. !Nara – fruit for development of the !Khuiseb Topnaar. Namib Scientific Society, Windhoek.

Jürgens N and Haarmeyer DH. 2010. Gobabeb (S35). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Nacoma 2010. Environmental management plan for the town of Lüderitz. Unpublished report for Namibia Coastal Management Project, Ministry of Environment and Tourism.

Strohbach BJ and Haarmeyer DH. 2010. Rooisand (S37). In Jürgens N, Schmiedel U and Hoffman MT (eds). Biodiversity in southern Africa. Klaus Hess Publishers, Gottingen and Windhoek.

Ward, J.D. and Breen, C.M. 1983. Drought stress and the demise of Acacia albida along the lower Kuiseb River, Central Namib Desert: preliminary findings.

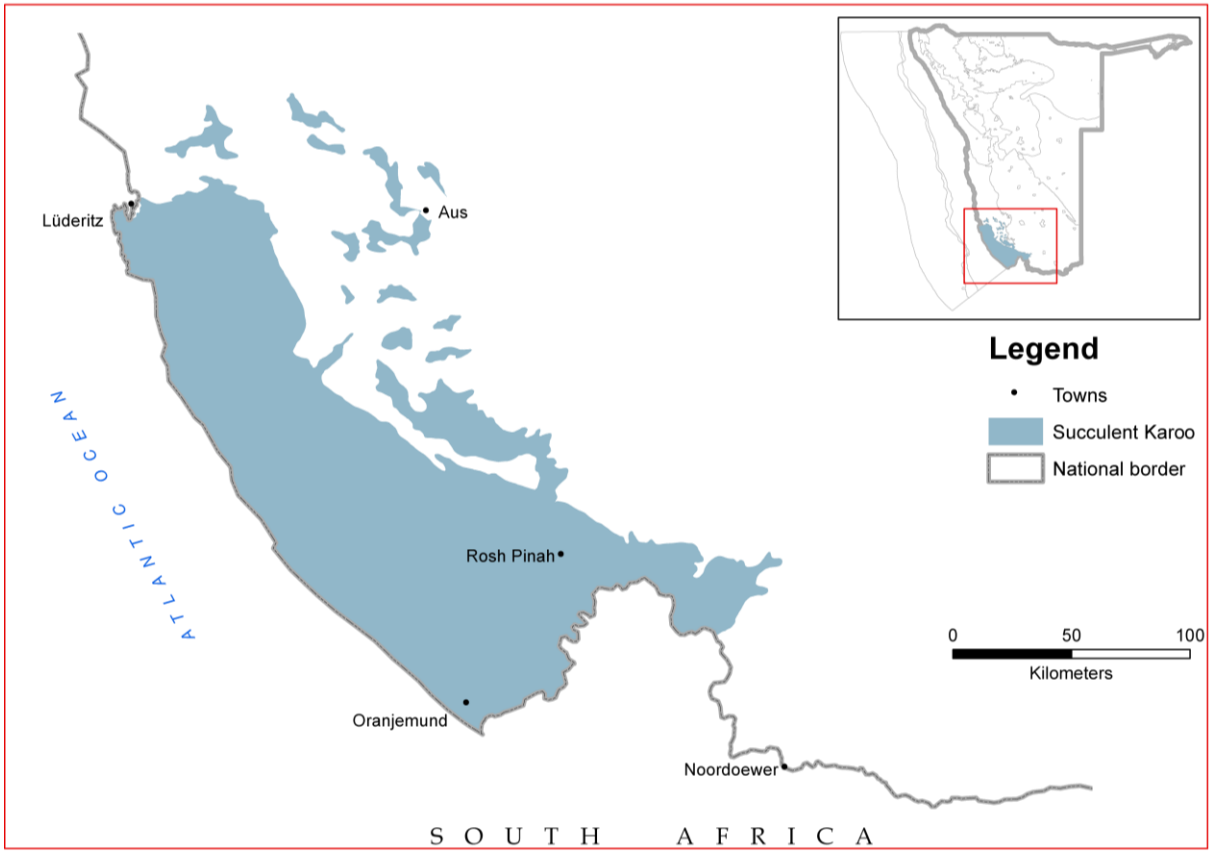
5.12 Succulent Karoo

5.12.1 Description and assessment of ecosystem zone

5.12.1.1 Main attributes and ecological processes

The Succulent Karoo occupies an area of approximately 20,000 km^2 in the extreme south-western corner of Namibia, as shown in Figure 26. It extends from the Orange River mouth to just east of the confluence with the Fish River in the south, and north to about Lüderitz and Aus. Isolated pockets of Succulent Karoo appear on the higher slopes of escarpments, mountain ranges and inselbergs to the east and north of the main part of the zone. It is a northern extension of the larger ecosystem zone that occurs from just north of Cape Town in South Africa and extends in a narrow belt into Namibia.

Figure 26: Location of the Succulent Karoo ecosystem zone within Namibia



Most of the Succulent Karoo in Namibia occurs on gently rising coastal sandy and gravel plains between sea level and about 500 m with small inselbergs and low ranges. On the eastern edge the land rises into larger hills up to about 1,200 m, and the isolated pockets of Succulent Karoo to the north and east of the main biome are found on escarpments and mountain ranges that rise up to about 1,600 m above sea level.

This biome is characterised by dwarf succulent vegetation which in turn is linked to the pattern of rainfall. The area typically receives about 50 mm of rain per year, and up to about 100 mm on its eastern border. Some 60% of this rain falls in winter, as part of frontal systems passing the Cape in South Africa. All other areas of Namibia receive summer rainfall. As in all hyper-arid climates, the rainfall is highly unpredictable with a coefficient of variance of about 60%.

Coastal fog is an important form of precipitation, exceeding rainfall by up to five times in some places. Two types of fog occur: advective fog which occurs typically below 200 m and can be carried up to 15 km inland; and high fog, typically at 100-600 m and can penetrate up to 60 km from the coast, coming into contact with higher ground on 60-120 days per year. Lüderitz experiences fog on about 115 days per year and Oranjemund on about 81 days.

The Succulent Karoo is a biodiversity hotspot: the most important such arid site on a global scale, and subsequently identified as one of the world's 25 most important biodiversity hotspots. The whole Succulent Karoo, covering both the Namibian and South African components, supports about a third of the world's succulent plant species. In addition to its high succulent plant diversity, the zone also has a high diversity of reptiles, scorpions and insects. It also has high levels of endemism in all these groups, with some areas holding highly range-restricted groups of species.

5.12.1.2 Human activity and population

Rosh Pinah is the only recognised urban area in the Succulent Karoo. It has an estimated population of 2,800, but was not listed as an urban area in the 2001 census for comparison. The towns of Lüderitz and Oranjemund partially fall within the zone, and are described in the Coastal and Near-Shore zone (Section 5.12.4).

More than 90% of the Succulent Karoo is contained within the Tsau //Khaeb National Park, and some more falls within the Ai-Ais Hot Springs National Park.

5.12.1.3 Pressures and drivers of change

Table 52: Broad drivers of change and ecosystem-specific pressures in the Succulent Karoo ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Overgrazing and large-scale strip-mining
Exploitation	Abstraction of surface water from the Orange River, particularly upstream in South Africa
Pollution	Pollution of the Orange River, particularly upstream in South Africa
Invasive species	No relevant pressures identified in this zone
Climate change	More arid climate
Illegal use	Poaching of wildlife, illegal offtake of succulent plants

Table 52 relates the six broad categories of drivers of change to specific pressures within the Succulent Karoo ecosystem zone. As more than 90% of the ecosystem zone falls within State Protected Areas, there are fewer pressures than in some other ecosystem zones. Indeed, the major driver of change has been habitat change as a result of overgrazing on the very marginal rangelands in the zone; the damage caused by limited access to the eastern parts of the Succulent Karoo during a severe drought in the 1980s is still visible in some places.

Minor pressures are more varied but still fairly limited. Abstraction of surface water from the Orange River, as well as its pollution from industrial and agricultural activities upstream in South Africa has impacted on flows and water quality; this has particular impacts at the coast. There is thought to be some illegal offtake of wildlife resources, which may be as a result of the expansion of Rosh Pinah

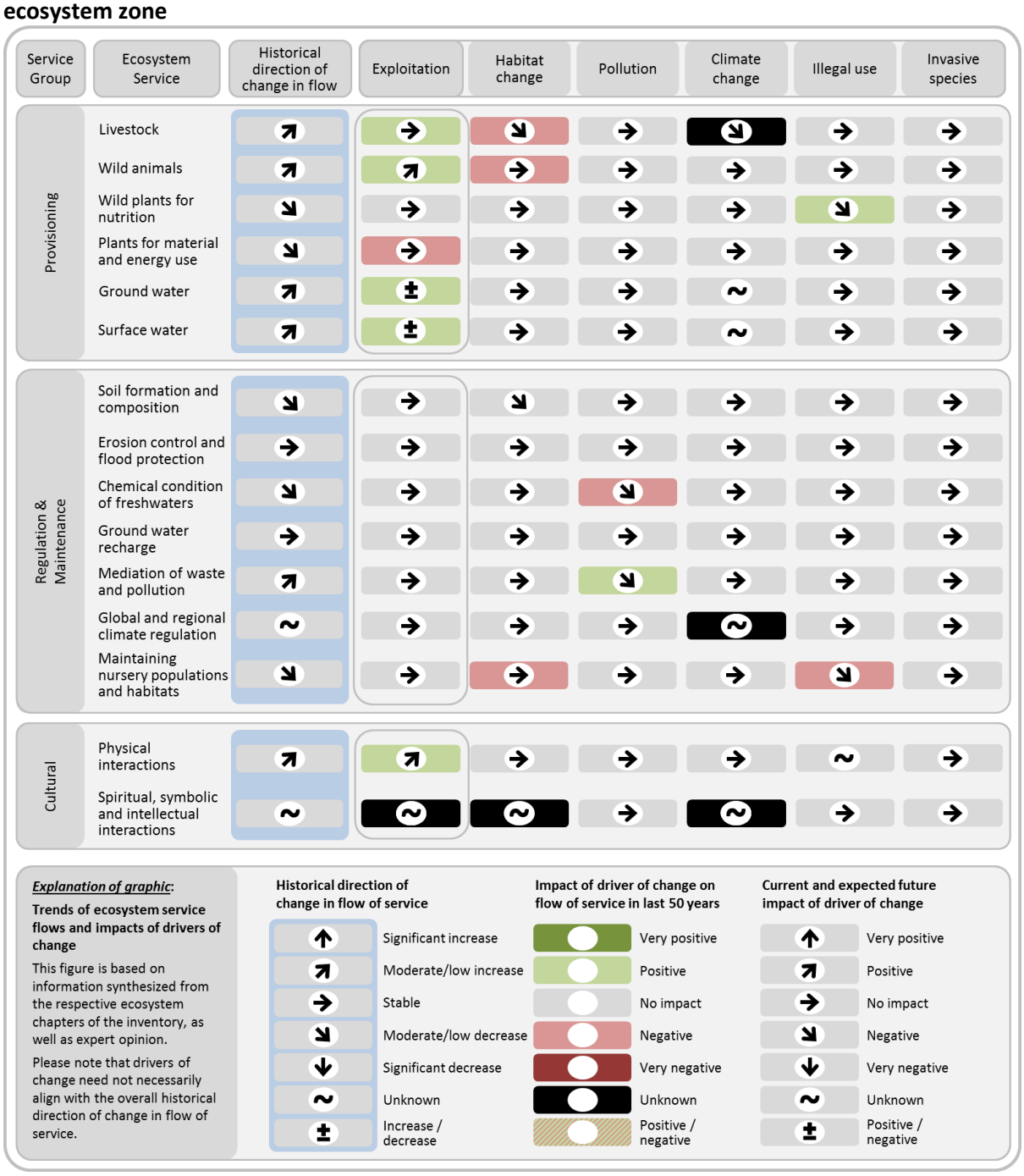
and unemployment in the town. The illegal harvesting of succulent plants is a concern for some species.

The impact of climate change on coastal fog is poorly understood, and no clear projections are currently available. A decrease in coastal fog would, however, have a negative impact on the succulent vegetation, and the areas covered by the ecosystem zone would be expected to shrink towards the south and west. Extensive areas close to the coast have been stripped for diamond mining, but in the last decade the diamond mining footprint has decreased somewhat in this zone and post-mining habitat rehabilitation is taking place.

5.12.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Succulent Karoo ecosystem zone. Figure 27 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 27: Overview of flows of services and impacts from drivers of change in the Succulent Karoo ecosystem zone



5.12.2.1 Provisioning

Table 53 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Succulent Karoo (and which are comparable to those classes specified in Figure 27). It

also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 53: Overview of provisioning services in the Succulent Karoo ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Reared animals and their outputs	Limited production of meat from livestock (primarily goats and sheep)	National	Consumptive use
Wild plants, algae and their outputs	Limited production of skins and trophies from livestock and wildlife	International	Consumptive use
Wild plants, algae and their outputs	Succulent plants	Local	Consumptive use
Wild animals and their outputs	Meat from wildlife	Local	Consumptive use
Surface water for drinking	Drinking water from the Orange River (Oranjemund, Rosh Pinah)	Regional	Consumptive use
Groundwater for drinking	Drinking for rural residents from aquifers	Local	Consumptive use
Materials from plants, algae and animals for agricultural use	Fodder	Local	Consumptive use
Surface water for non-drinking purposes	Water from the Orange River for domestic, mining and industrial use (e.g. Rosh Pinah, Orange River mines); farms/tourism establishments; and livestock and wildlife	Regional	Consumptive use
Groundwater for non-drinking purposes	Domestic water for farms/tourism establishments; wildlife and livestock from aquifers	Local	Consumptive use

Description

There is very limited livestock farming (primarily goats and sheep) on freehold farms to the east of the zone. This freehold land has increasingly been converted to wildlife-based land uses, and consequently some wildlife is hunted for meat, as well as being used to produce skins and trophies. Succulent plants are also harvested in the zone, while fodder is used to provide feed for livestock.

Drinking and non-drinking water for the small population of rural residents is pumped from local aquifers; this is also used to support populations of livestock and wildlife. Water from the Orange River is pumped to Oranjemund and Rosh Pinah for drinking and domestic use, as well as mining and industrial purposes; it is also used to supply some farms and tourism establishments.

Affected population

Surface water for drinking and non-drinking purposes is relevant to regional populations, as it is used to supply the towns of Oranjemund and Rosh Pinah. Some of the meat and dairy from small stock

farming is commercially marketed, while trophies are exported internationally; other services are generally used at the point of extraction or harvesting, and are consequently relevant at a local level.

Change in flow over past 50 years

The flow of most of the provisioning services is not thought to have changed significantly in recent decades. Livestock farming has probably decreased in favour of wildlife-based land uses (and consequently so has the use of fodder), while meat from wildlife, the harvesting of succulent plants and the production of animals products have likely increased slightly.

Water for rural residents and drinking water in towns has grown slowly overall as rural populations have fallen sharply in recent years and Oranjemund and Rosh Pinah are only growing slowly, if at all. The exploitation of Orange River water for mining and industrial use has increased from the establishment of Skorpion Mine in 2001.

Pressures and expected impacts on flow of service

The farming of livestock is not expected to grow any further and there may be increased pressure on carrying capacity as a result of land degradation and climate change. Meat from wildlife may continue to grow while the production of skins and trophies is also expected to increase. Pressure from illegal harvesting of succulent plants may increase unless measures are taken to address it.

The future flows of provisioning services related to water are projected to vary depending on what they are used for. Drinking water for rural residents is likely to decline as populations shrink, while drinking water for towns is likely to stabilise. An increase in the provision of water for farms and tourism establishments is expected, as is water for mining and industrial uses.

5.12.2.2 Regulation and maintenance

Table 54 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Succulent Karoo.

Table 54: Overview of regulation and maintenance services in the Succulent Karoo ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Bio-remediation by micro-organisms, algae, plants, and animals	Detoxification of pollutants in rivers	Regional	Indirect use
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants etc.	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of pollutants in rivers	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of gases in atmosphere	Regional	Indirect use
Buffering and attenuation of mass flows	Transport and storage of sediments	Regional	Indirect use
Hydrological cycle and water flow maintenance	Groundwater recharge	Regional	Indirect use
Flood protection	Flood protection by appropriate land coverage	Local	Indirect use
Maintaining nursery populations and habitats	Endemic succulents, reptiles and invertebrates	National	Indirect use
Weathering processes	Decomposition/mineralisation of dead organic material, nitrification	Local	Indirect use
Decomposition and fixing processes	Maintenance of fertility of soils, nutrient storage and soil structure	Local	Indirect use
Chemical condition of freshwaters	Maintenance of condition	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Maintenance of regional precipitation/temperature patterns	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances occurs through the absorption and dilution of pollutants, both at the atmospheric level and by features of rivers (including the organisms within them and through their flow).

The mediation of flows happens at two levels: mass flows, through the transportation and storage of sediments along the Orange River; and liquid flows, relating to groundwater recharge and flood protection. Relevant services in the maintenance of physical, chemical and biological conditions

division are more broadly defined. As well as including soil formation and composition, (through both the decomposition/mineralisation of dead organic material and nitrification, as well as the maintenance of the fertility of soils, nutrient storage and their soil structure) and atmospheric composition and climate regulation (through carbon sequestration and the maintenance of regional precipitation/temperature patterns), the Succulent Karoo provides the habitat for a significant number of endemic succulent plants, reptiles and invertebrates. The maintenance of the condition of the Orange River is also an important service.

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the mediation of mass and liquid flows (although flood protection is more relevant to local populations). The services within the soil formation and composition group are primarily relevant to local populations, as they support activities that occur on a local level. Maintenance of the condition of the Orange River is important regionally as it effects downstream interactions. Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level.

Change in flow over past 50 years

Detoxification and dilution of pollutants has increased in recent decades as a result of increased pollution upstream in South Africa and return flows from irrigation schemes; for similar reasons the condition of the Orange River has likely declined. The transport and storage of sediments in the river are also thought to have increased, partially as a result of these return flows. The condition of the wetland at the Orange River mouth is now officially classified as Degraded, with its listing on the Montreux Record in 1995.

The habitat for endemics has been under pressure from their illegal use, and some habitat change as a result of land degradation. Similarly, overgrazing in some areas is likely to have reduced the fertility and structure of soils. There are not thought to be any distinct changes in flow relating to the other regulation and maintenance services.

Pressures and expected impacts on flow of service

The capacity of the river to detoxify and dilute pollutants may be limited in future if flows are significantly reduced; this could also be the case for the transport and store of sediments. The condition of the Orange River is expected to continue declining unless action is taken. Endemic succulents and reptiles are thought to be under ongoing pressure from their illegal use. There is expected to be a decline in precipitation as a result of climate change which would negatively affect micro and regional climate regulation.

5.12.2.3 Cultural

Table 55 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Succulent Karoo.

Table 55: Overview of cultural services in the Succulent Karoo ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Landscape appreciation; some wildlife viewing	International	Non-consumptive use
Physical use of land-/seascapes in different environmental settings	Some recreational hunting	International	Consumptive use
Scientific	Research on endemics, degradation as a result of overgrazing, many other sources	International	Non-consumptive use
Heritage, cultural	Kolmanskop and other abandoned mining towns	International	Non-consumptive use; bequest; existence
Aesthetic	Kolmanskop in photographic representations	International	Non-consumptive use
Symbolic	Kolmanskop as representation of Namibia	International	Non-consumptive use
Existence	Relating to endemics	International	Existence
Bequest	Relating to endemics	International	Bequest

Description

A major tourism attraction in the zone is Kolmanskop, the abandoned mining town which has been overrun by the desert. Other non-consumptive tourism involves landscape appreciation and some wildlife viewing, and there is also some recreational hunting on private farms. There is scientific research that looks at the endemics in the zone and the effects of human interactions.

Kolmanskop also generates wider cultural services given its history, representations in media and its place as somewhat symbolic of Namibia. There are also existence and bequest services with respect to the endemics and the landscape in the zone.

Affected population

Tourists to the zone are primarily international visitors, and all other services also have relevance to international populations.

Change in flow over past 50 years

Recreational tourism has increased in recent decades; scientific services are also thought to have increased. The flow of services relating to other cultural services is not well understood.

Pressures and expected impacts on flow of service

Recreational tourism could increase further, particularly if the Tsau //Khaeb National Park is opened to public tourism. The effects of pressures on other cultural services are generally poorly understood.

5.12.2.4 Interactions between ecosystem services

There are some threats from upstream uses of Orange River water reducing flows and potentially reducing water quality, while these also could contribute to downstream impacts at the river mouth and the Coastal and Near-Shore zone.

5.12.3 Criteria for prioritisation of ecosystem services

5.12.3.1 Current and future expected impacts on the flow of the service

Services relating to soil formation and composition have been reduced as a result of short periods of grazing in the zone in the 1980s; these impacts can still be seen today. Negative pressures are also being felt on succulent plants, many of which are endemic to the zone, as a result of illegal harvesting.

5.12.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

The use of water in this ecosystem zone is not thought to be unsustainable.

Expansion of urban areas and increasing industrialisation

There are possible threats from industrial developments near the border of the Succulent Karoo and the Coastal and Near-Shore zone around Lüderitz, including a petrol refinery, phosphate treatment plant, and storage facilities for manganese and coal linked to the industrial port development on the Lüderitz peninsula.

Threats and impacts of climate change

The threats and impacts of climate change are unclear, but they could reduce the capacity of the edges of the ecosystem zone to be used for agriculture, and potentially impact groundwater and surface water services.

Rapid expansion of mining and prospecting

There is continued and growing mining in the zone, both for base metals (Rosh Pinah, Skorpion, the proposed Gergarub mine) and for diamonds. Terrestrial diamond mining (e.g. along the Orange River and at selected coastal sites) adds to the footprint of the last century of diamond mining along the coast between Oranjemund and Lüderitz.

Unsustainable land management practices

Land degradation occurred as a result of a brief period of grazing during the 1980s and a long history of diamond mining, and these effects can still be seen today. Current land uses are thought to be sustainable.

Uncontrolled bush fires

Uncontrolled bush fires are not a threat in this ecosystem zone.

Alien invasive species

Alien invasive species are found along the Orange River.

Illegal harvesting and trade of wildlife and forest and plant resources

The illegal harvesting of succulent plants could represent a threat, and there is thought to be some poaching of wildlife in the zone.

Human-wildlife conflict

There is limited human-wildlife conflict in this ecosystem zone.

5.12.3.3 Economic importance (current and potential)

Recreational tourism is an important economic activity that has the potential to grow, especially if the Tsau //Khaeb National Park is developed.

5.12.3.4 Affected population (size and socio-economic characteristics)

Recreational tourism probably affects the greatest population in the zone given its focus on conservation land uses. The maintenance of nursery populations is also important, given that the Succulent Karoo is a world-renowned biodiversity hotspot.

5.12.3.5 Availability of data

Research surrounding the ecosystem zone's status as a biodiversity hotspot should have data which may be applicable to estimate flows of certain ecosystem services. Estimates of the number of tourists visiting and staying in the zone should be available.

5.12.4 References

Barnard, P. (ed.) 1998. Biological diversity in Namibia: a country study. Windhoek: Namibian national Biodiversity Task Force.

Giess, W. 1971. A preliminary vegetation map of South West Africa. Dinteria 4: 1-114

Jacobson, P.K., K.M.Jacobson and M.K.Seely. 1995. Ephemeral rivers and their catchments: Sustaining people and development in western Namibia. Desert Research Foundation of Namibia, Windhoek.

Macfarlane, D.M. 2013. Strategic Management Plan for the Orange River Mouth Ramsar site. Report prepared for the United Nations Office for Project Services (UNOPS).

Shortridge, G.C. 1934. The mammals of South West Africa. Vols 1 & 2. London: Heinemann.

Turpie J, Midgley G, Brown C, Barnes J, Pallett J, Desmet P, Tarr J, Tarr P. 2010. Climate change vulnerability and adaptation assessment for Namibia's biodiversity and protected area system. Final Report to Ministry of Environment and Tourism, by Anchor Environmental Consultants, Namibia Nature Foundation and Southern African Institute for Environmental Assessment.

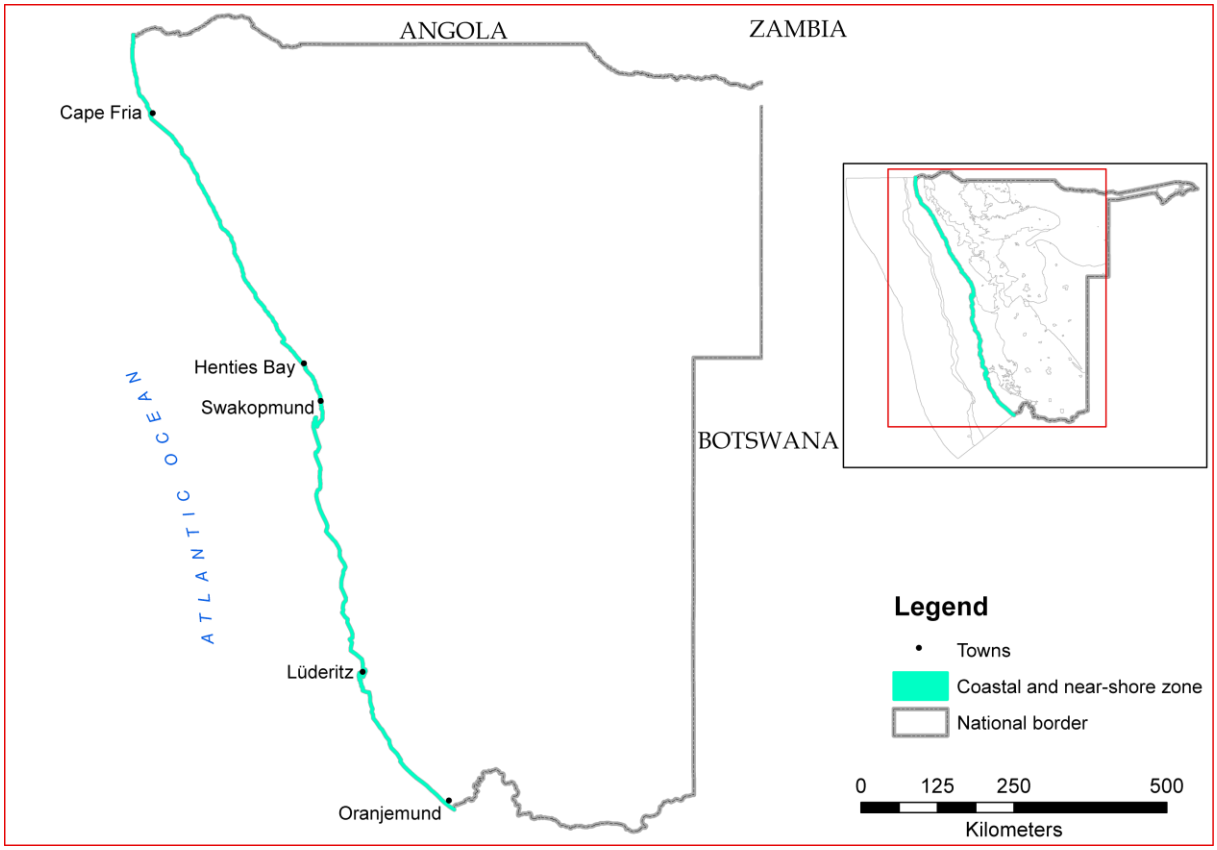
5.13 Coastal and Near-Shore

5.13.1 Description and assessment of ecosystem zone

5.13.1.1 Main attributes and ecological processes

The Coastal and Near-Shore ecosystem zone encompasses ecologically distinct units from 1 km inland to the shore itself (intertidal and subtidal zones) and the near shore marine environment (to about 30 m depth). There are naturally strong ecological connections between the ecologically distinct zones within the Coastal and Near-Shore zone, as well as with adjoining ecosystem zones, both inland and marine. The Coastal and Near-Shore ecosystem zone is presented in Figure 28.

Figure 28: Location of the Coastal and Near-Shore ecosystem zone within Namibia and Namibian offshore areas



The zone borders the Northern Namib, Namib Sand Sea and the coastal part of the Succulent Karoo desert ecosystem zones from north to south. Within these zones, the coastal fringe is distinguished by modified abiotic conditions (strong influence of coastal fog, increased wind speeds, low diurnal and seasonal ambient temperature amplitudes, influence of sea spray etc.) which in turn have a large influence on the ecological processes of the Coastal and Near-Shore ecosystem zone. In addition, the availability of abundant marine life at the shore itself (intertidal animals and algae, beach-cast kelp and seaweed, fur seal and seabird colonies, stranded cetaceans etc) allow an important influx of marine nutrients into the desert ecosystem zone.

The geomorphology of this coastal zone is varied and ranges from active estuaries and ephemeral river mouths to rocky cliffs, sandy beaches backed by coastal dunes or saltpans. The great majority

of the coast is exposed to oceanic swells (with an average direction from the south west) and protected bays and coastal wetlands are particularly scarce (but important for biodiversity). Along the southern half of the coast are a few rocky islands which provide the only natural breeding habitat for extensive seabird (and some fur seal) colonies.

The unique ecological conditions encountered along the coast have resulted in an extremely high degree of endemism in most groups of living organisms from plants and lichens to arthropods, reptiles etc. Similarly the near shore marine component is characterized by high abundance and diversity with also a high degree of (regional) endemism in groups like seaweeds, molluscs, crustaceans, fish and seabirds and marine mammals. In addition the coastal zone also constitutes an important migratory corridor for many shore and sea-birds, and cetaceans.

5.13.1.2 Human activity and population

There are two major towns along the Namibian coastline: Walvis Bay and Swakopmund. The former was, until recently, the second largest urban area in Namibia, and its population was estimated at around 62,000 in 2011. The population of Swakopmund was estimated at 45,000 in 2011, but has grown more rapidly (by 88%) since 2001 than Walvis Bay (42%). Other smaller towns include Lüderitz, which has a population of around 12,500 that has fallen by almost 6% since 2001, Henties Bay (4,700, an increase of more than 40% since 2001) and Oranjemund (3,900, a decrease of 12% since 2001).

Due to its inaccessibility, scarcity of water and harsh climate, the coastal zone is otherwise only extremely sparsely populated outside of these towns. Any coastal populations outside these urban areas are described in the sections corresponding to the relevant inland ecosystem zones that border the Coastal zone.

The majority of the Namibian coastline, aside from the townlands, falls within a series of contiguous protected areas, from the Kunene River in the north leading into the Skeleton Coast Park, the Dorob National Park, the Namib-Naukluft, and finally the Tsau //Khaeb before reaching the Orange River in the south. The Namibian Islands' Marine Protected Area is also primarily within the Near-Shore zone. The Orange River mouth has been designated a Ramsar site.

5.13.1.3 Pressures and drivers of change

Table 56: Broad drivers of change and ecosystem-specific pressures in the Coastal and Near-Shore ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Onshore diamond mining; off-road driving
Exploitation	Over-exploitation of fish resources; upstream abstraction of water from rivers (Orange and Kunene in particular)
Pollution	Coastal littering; industrial effluents; noise pollution from flights over the coast; marine noise pollution and disturbance; shipping activity
Invasive species	Mariculture presents threat of invasive/detrimental species being introduced
Climate change	Sea level rise; potential for increased winter storm frequency and changes in local atmospheric pressure fields
Illegal use	Low (unpermitted) flights over the coast; illegal fishing

Table 56 relates the six broad categories of drivers of change to specific pressures within the Coastal and Near-Shore ecosystem zone. Due to the extent of human activity along the Namibian coast and its interaction with other neighbouring ecosystem zones, both inland and marine, there are a wide range of pressures identified for the Coastal and Near-Shore zone.

Onshore diamond mining affects sediment movements along the shore, with possible impacts on turbidity, smothering of kelp beds and fragile intertidal ecosystems and changes in the shoreline (as a result of the possible build-up of sand bars and tombolos) which might permit land predators access to some of the seabird islands. Habitat change is also occurring as a result of off-road driving and the unregulated or illegal use of quad-bikes in sensitive areas, which in particular leads to degradation of the landscape and direct harm to shorebirds and seabirds (e.g. disturbance of breeding colonies of the near-endemic Damara Tern), unique lichen communities (particularly in the Dorob National Park) and endemic succulent communities (Lüderitz peninsula). Both off-road driving and coastal mining have negative impacts on the ecologically important littoral hummock vegetation.

A major driver of change in Namibian marine environments has been over-exploitation of the fish resources. This overexploitation is discussed in greater detail in Sections 5.13.4, 5.14.4, and 5.15.4, but with regard to the Coastal and Near-Shore zone, the overfishing of small pelagic fish over the shelf has been the main cause of the decline of many species of seabirds breeding along the coast and on the islands (in particular the Cape gannet, African penguin and Cape cormorants); it has also affected the distribution of the Cape fur seal. Overexploitation of fish resources has also occurred within the Coastal and Near-Shore zone with respect to other species; this is also compounded by illegal fishing in some cases.

Abstraction of water upstream from the Kunene and Orange Rivers, as well as changes in water quality due to pollution from industry and agriculture, impact on the functioning of the mouths of the two rivers. The Orange River mouth, a declared Ramsar site, has been classified as degraded.

Pollution also arises from a number of activities in the zone: low (and often illegal) flying over the coast; onshore littering; the discharge of effluents from industrial developments at the coast (for

example, the dumping of organic waste by fish factories, the release of fines (tailings) in the shore zone due to diamond processing); organic effluent and chemicals from mariculture; and shipping activity primarily related to the port at Walvis Bay. The mariculture sector also represents a potential threat of introducing invasive species that could be detrimental to local marine species.

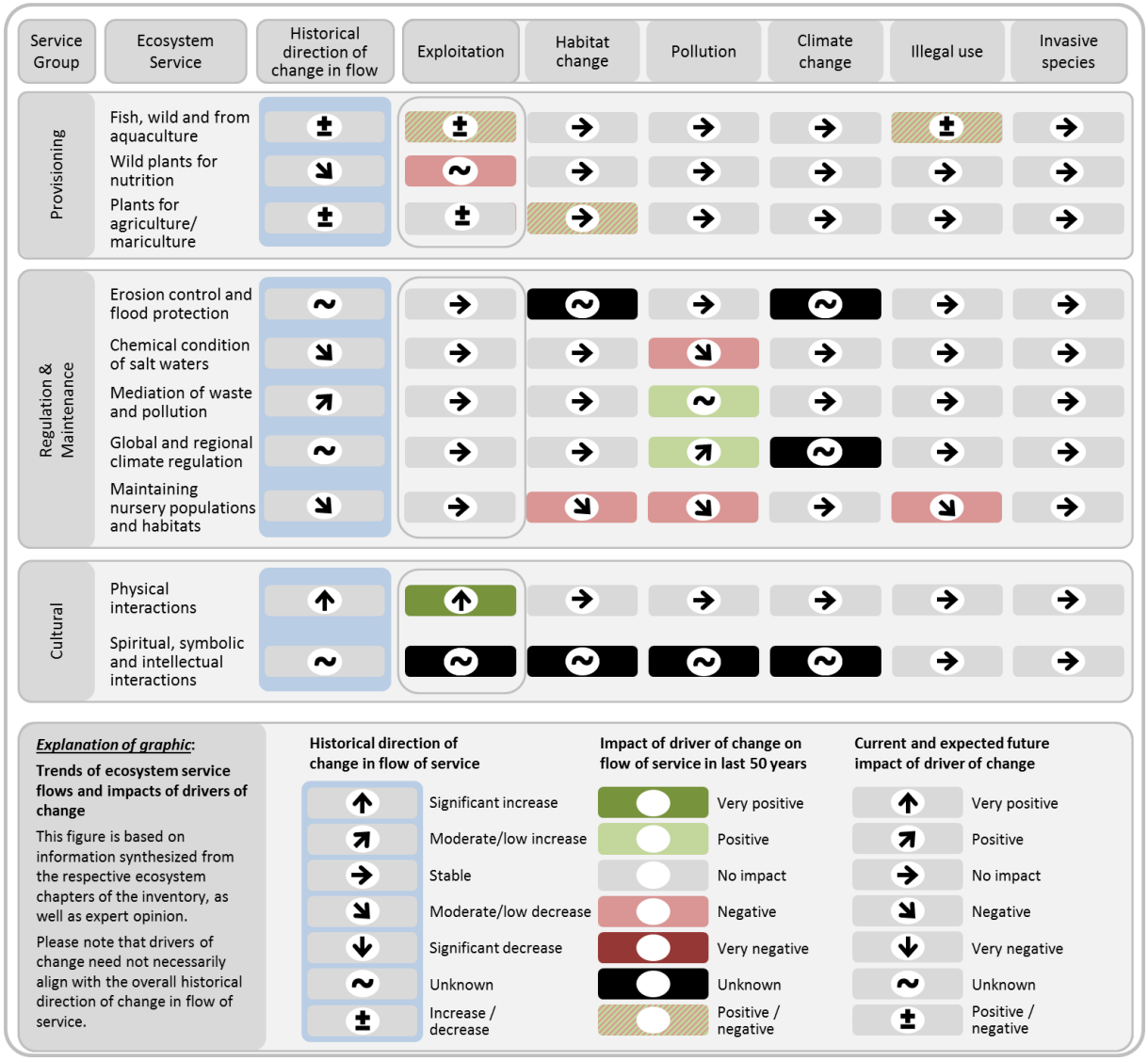
Sea level rise (linked to climate change) is at present close to the world average (approximately 3 mm per year) in the region and is predicted to accelerate. This, together with possibly increasing winter storm frequency and changes in average local atmospheric pressure fields (more frequent coastal lows) is predicted to affect the sandy shores considerably through coastal erosion in some places and coastal accretion in others.

5.13.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Coastal and Near-Shore ecosystem zone. Figure 29 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 29: Overview of flows of services and impacts from drivers of change in the Coastal and Near-Shore ecosystem zone

14,94



5.13.2.1 Provisioning

Table 57 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Coastal and Near-Shore zone (and which are comparable to those classes specified in Figure 29). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 57: Overview of provisioning services in the Coastal and Near-Shore ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Wild plants, algae and their outputs	Seaweed/Agar	International	Consumptive use
Wild animals and their outputs	Rock Lobster, snoek, kob, fur seals	International	Consumptive use
Wild animals and their outputs	Line fish	Local	Consumptive use
Animals from in-situ aquaculture	Oysters, Abalone	International	Consumptive use
Materials from plants, algae and animals for agricultural use	Kelp for abalone farming	Regional	Consumptive use
Materials from plants, algae and animals for agricultural use	Guano - fertiliser	International	Consumptive use

Description

The main commercial fishing in this zone is of Rock Lobster, and to a lesser extent Snoek and Kob. There is also recreational fishing off the coast for some food, as well as fishing by local communities for own use. Beach casts of seaweed were previously collected around Lüderitz for agar production and export, but this activity has since been abandoned due to fluctuations in market value and the destruction of the main processing centre in Japan following the 2011 Tsunami. Kelp species are still collected for use as natural feed in Abalone farming, which occurs along with Oyster farming along the Namibian coast. The production of guano for use as fertiliser occurs on the bird islands, while fur seals at south of Lüderitz and at Cape Cross are used for the production of fur.

Affected population

The collection of seaweed for the production of agar, commercial fishing, production of fur, guano farming and mariculture activities of farming oysters and abalone are relevant internationally as they are exported. The collection of kelp for abalone farming is relevant regionally within the ecosystem zone, while fishing for local communities and by tourists is relevant only locally.

Change in flow over past 50 years

The collection of seaweed has stopped in recent years as discussed above, so this service has declined. Catches of Rock Lobster have also declined following a drastic reduction in the stock accompanied by a reduction in quotas: from 2000 tons per annum prior to independence to 300 tons in 2013/14. This is due to a combination of overfishing and possible changes in the dynamic of the stock. The guano industry has collapsed as a result of the effective disappearance of the small pelagic stocks over the shelf (See Section 5.14.4), and the resulting decline in seabirds.

Recreational line fishing for food and by local communities is thought to have increased in recent decades as tourism has also increased. The collection of kelp has increased to support the growth of the mariculture activities in the zone.

Pressures and expected impacts on flow of service

Fishing on a local basis is expected to continue growing as populations increase, but there are also likely to be negative pressures from illegal fishing for the same reason. The effects on the Rock Lobster fishery are less clear: if there have been changes in the dynamic of the stock, then measures to rebuild the stock may be fruitless, and the growth of coastal populations also puts pressure on the stock from illegal fishing. There is still potential for the collection and sale of seaweed for the production of agar, but this depends on international markets.

The mariculture activities of oyster and abalone farming are expected to continue growing as world markets grow, and the collection of kelp should also increase to support these activities. No recovery in the guano industry is expected unless significant measures are taken with regard to rebuilding the small pelagic stocks.

5.13.2.2 Regulation and maintenance

Table 58 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Coastal and Near-Shore zone.

Table 58: Overview of regulation and maintenance services in the Coastal and Near-Shore ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Bio-remediation by micro-organisms, algae, plants, and animals	Waste water cleaning	Regional	Indirect use
Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	Absorption of pollutants	Regional	Indirect use
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of pollutants	Regional	Indirect use
Flood protection	Flood protection by coastal features	Local	Indirect use
Maintaining nursery populations and habitats	Natural breeding habitats for seabird and fur seal colonies; NIMPA islands; high (regional) endemism of seaweeds, molluscs, crustaceans, fish, seabirds, marine mammals	International	Indirect use
Chemical condition of salt waters	Maintenance of condition of sea water	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Coastal fog, winds, temperatures	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances occurs both at the level of the ecosystem zone (absorption of pollutants into the atmosphere; dilution of pollutants in seawater) and at the level of biota (absorption of pollutants and detoxification/waste water cleaning by micro-organisms). The mediation of flows relates to the flood protection provided by various coastal features.

Relevant services in the maintenance of physical, chemical and biological conditions division are more broadly defined. The Coastal and Near-Shore zone represents a breeding habitat for seabird and fur seal colonies, as well as a habitat for a number of other endemic species, such as seaweeds, molluscs, crustaceans, fish and marine mammals (maintaining nursery populations and habitats). There are also services relating to the maintenance of the condition of sea water, carbon sequestration, and micro and regional climate regulation (e.g. maintenance of the coastal fogs, winds and temperatures).

Affected population

Services relating to the mediation of waste, toxins and other nuisances are relevant to regional populations, as these generally occur at the whole ecosystem level; this is also the case for the maintenance of the condition of sea water. Flood protection is of most benefit to local populations. Carbon sequestration affects global populations, while the maintenance of regional precipitation/temperature patterns is important at a regional level. The maintenance of nursery populations and habitats is relevant to international populations because many of these species are either regional endemics or threatened migrants.

Change in flow over past 50 years

The relevant services within the mediation of waste, toxins and other nuisances division have all increased in recent decades as a result of increased pollution from human activity along the coast and in the near-shore zone. The maintenance of the condition of sea water service has declined for the same reason.

The collapse of the small pelagic fish stocks along the shelf (see Section 5.13.4) has resulted in a significant decline in the numbers of seabirds that breed along the coast and on the islands (such as the Cape gannet, the African penguin and Cape cormorants), and consequently the effectiveness of the NIMPA and the service of the breeding habitats has declined significantly There has also been pressure on the habitats of endemic plants and shorebirds as result of habitat change through off-road driving. The overall change in flow of flood protection, carbon sequestration and micro and regional climate regulation is unknown.

Pressures and expected impacts on flow of service

Pollution is expected to be a continued pressure in the zone, and so the services relating to the mediation of waste, toxins and other nuisances are expected to become increasingly important; however it is unclear to what extent the ecosystem zone will have the capacity to mediate these increased pollutants. Sea water quality in the near-shore area is expected to continue declining for similar reasons.

There is not expected to be any major change in the service relating to the natural breeding habitats for seabirds and the NIMPA; it appears that this would require a recovery in the small pelagic stocks along the shelf. Pressures on the habitats of endemic species are expected to continue growing as a result of increased tourism that in turn leads to more off-road driving. Carbon sequestration is likely to continue increasing as emissions of carbon increase. Climate change represents an ongoing pressure on flood protection and micro and regional climate regulation, but its effects are unclear.

5.13.2.3 Cultural

Table 59 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Coastal and Near-Shore zone.

Table 59: Overview of cultural services in the Coastal and Near-Shore ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Experiential use of plants, animals and land-/seascapes in different environmental settings	Recreational tourism: viewing of marine/coastal animals and seabirds; Shipwrecks	International	Non-consumptive use
Physical use of land-/seascapes in different environmental settings	Angling, recreational fish, sports activities: land-based, aerial-based, sea-based (kayaking, sailing)	International	Consumptive use/non-consumptive use
Educational	Education around the marine environment	National	Non-consumptive use
Heritage, cultural	Replicas of markers of first European visitors; shipwrecks; archaeological coastal sites; natural monuments	International	Non-consumptive use
Aesthetic	Representations of Namibian coastline	International	Non-consumptive use
Symbolic	Skeleton Coast as symbolic of Namibia	International	Non-consumptive use
Existence	Relating to marine mammals and birds; landscapes	International	Existence
Bequest	Relating to marine mammals and birds; landscapes	International	Bequest
Scientific	Various research topics for example relating to endemic species; SANUMARC in Henties Bay; Lüderitz Marine Research Laboratory	International	Non-consumptive use

Description

Tourism is a major cultural service in the Coastal and Near-Shore zone. It involves activities such as the viewing of coastal and marine animals and birds; recreational fishing; off-road driving and sandboarding on the dunes; skydiving; kayaking; and sailing.

The endemic and near endemic species found along the coast, as well as the nature of the ecosystem, give rise a wide range scientific services, in particular research. The Orange River Mouth, Sandwich Harbour, and the Walvis Bay Lagoon have been designated as Ramsar Sites and are consequently of significant scientific and ecological importance. The Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC) is part of the University of Namibia (UNAM) campus located just to the north of Henties Bay, and engages in research and development activities in the field of marine and coastal resources. The Coastal and Near-Shore zone also provides the opportunity for educational services surrounding the coastal and marine environment.

There are significant heritage, historical and cultural services associated with the Namibian coastline. The coastal towns represent home or the place of birth of a large number of Namibians, as well as being the first landing point of Europeans centuries ago. Shark Island off Lüderitz was the site of an internment camp between 1904 and 1908, where up to 3,000 Herero and Nama people died. In addition, the coast generates aesthetic and symbolic services, as well as bequest and existence services derived from the species, landscapes and ways of life that it represents.

Affected population

Tourists to the zone are a mix of international and national visitors. All other services also have relevance to international populations, except education which is mainly relevant at a national level.

Change in flow over past 50 years

Recreational tourism has increased significantly in recent decades; scientific services related to research are also thought to have increased. However reduced flows and water quality, primarily as a due to upstream uses in South Africa, have resulted in the Ramsar Site at the Orange River Mouth being classified as 'degraded'. The flow of services relating to other cultural services is not well understood.

Pressures and expected impacts on flow of service

Recreational tourism is expected to continue increasing, especially as further facilities are being developed along the coast. The effects of pressures on other cultural services are generally poorly understood.

5.13.2.4 Interactions between ecosystem zones and ecosystem services

Recreational tourism is putting pressures on a number of other services in the zone: low flying over the coast is disrupting breeding activities of endangered seabirds; off-road driving is threatening endemic or near-endemic species onshore; overfishing (e.g. Rock Lobster) is threatening those very resources and their commercial fisheries; and littering is also affecting landscapes and terrestrial and marine wildlife. Mariculture in the zone could also increase risks of pollution and invasive species that are harmful to water quality or other local species.

There are also significant interactions with other ecosystem zones. The coastal fog in this zone is extremely important to neighbouring coastal zones as a source of water, primarily for vegetation but also in some cases humans. Upstream pollution and abstraction of water from the Orange River in neighbouring ecosystem zones and in South Africa has led to the Ramsar site being declared

degraded, while the collapse of the small pelagic fish stock has had significant negative impacts on the guano industry, as well as marine biodiversity.

5.13.3 Criteria for prioritisation of ecosystem services

5.13.3.1 Current and future expected impacts on the flow of the service

Increasing threats to nursery habitats of endemic and endangered species from habitat change, pollution and illegal activities are being experienced. Pollution is also threatening water quality in the coastal zone and further onto the shelf. Some overexploitation of fish resources (e.g. rock lobster) is also thought to be occurring, and guano production is expected to continue to decline (from already low levels)

5.13.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

The ecosystem zone has no sources of freshwater of its own, and water users are dependent on water being transferred from neighbouring ecosystem zones. The relatively large urban populations in towns along the coast are driving the overexploitation of some aquifers in neighbouring zones, for example Omdel in the Northern Namib and Koichab in the Namib Sand Sea.

Expansion of urban areas and increasing industrialisation

Increased industrialisation (e.g. proposed new ports at Cape Fria and Mile 14, deepening of Walvis Bay Harbour, port project on Lüderitz Harbour and associated industries such as phosphate processing) represents a threat to water quality in the zone.

Threats and impacts of climate change

Climate change could increase the frequency of storms, and lead to further coastal erosion and increased threats from flooding.

Rapid expansion of mining and prospecting

There is diamond mining both along the coast and in shallow offshore water. This may represent pressures such as pollution and disturbances to breeding habitats, as well as aesthetic disruption.

Unsustainable land management practices

Residential and other coastal developments, such as the proposed Desert Rose Casino, present possible threats from unsustainable land management practices in this ecosystem zone.

Uncontrolled bush fires

Uncontrolled bush fires are not thought to be a threat in this ecosystem zone.

Alien invasive species

The alien invasive Mediterranean Mussel, *Mytilus galloprovincialis*, is already present and has had a major detrimental effect on some indigenous mussel species. Additional alien invasive species may occur from the development of the mariculture sector, but they are likely to be contained to very

local areas. The development of fin-fish farms could represent a greater pressure, although this would be realised more through pollution impacts.

Illegal harvesting and trade of wildlife and forest and plant resources

There is some illegal/unregulated fishing in the zone.

Human-wildlife conflict

There is limited human-wildlife conflict in this ecosystem zone.

5.13.3.3 Economic importance (current and potential)

Recreational tourism is hugely significant for the local and national, being a draw for international and national tourists. The guano industry and the rock lobster fishery have the potential to contribute much more to the economy than currently, although this would require restorative measures.

5.13.3.4 Affected population (size and socio-economic characteristics)

Recreational tourism affects a significant population in the zone either directly or indirectly. It also extends to wider populations at a national level, as coastal towns are key destinations for domestic holidaymakers, as well as international populations. Cultural services relating to coastal environment are also important to national populations in Namibia.

5.13.3.5 Availability of data

It should be possible to estimates stocks and offtakes of fisheries in the zone, as well as the number of tourists. Research conducted by the NACOMA project, the Benguela Current Commission and institutes such as SANUMARC are important sources of data on a range of services. The Ministry of Fisheries and Marine Resources (MFMR) tracks catch for the main commercial species but lack of capacity is a problem.

5.13.4 References

Benguela Current Commission. 2011. Annual State of Fish Stocks Reports. Benguela Current Large Marine Ecosystem, 2nd Edition, 91 pp. BCC, Windhoek, Namibia.

Benguela Current Large Marine Ecosystem. 2007. Status of the Fishery Resources in the Benguela Current Large Marine Ecosystem. State of Stocks Review (Eds: Japp D.W., Purves M., Wilkinson S.). Report No 1, BCLME November 2007.

Boyer D.C., Hampton I. 2001. An overview of the living marine resources of Namibia. S. Afr. J. mar. Sci. 23: 5-35.

Currie H., Grobler K., Kemper J. (Eds). 2009. Namibian Islands' Marine Protected Area. Ministry of Fisheries and Marine Resources; Windhoek, Namibia. 136 pp.

Holtzhausen J.A, Kirchner C.H., Voges S.F. 2001. Observations on the linefish resources of Namibia, 1990-2000, with special reference to West Coast Steenbras and Siver Kob. S. Afr. J. mar. Sci. 23: 135:144.

Kemper J., Roux J-P., Bartlett P.A., Chesselet Y.J., James J.A.C., Jones R., Wepener S. and Molloy F.J. 2001. Recent population trends of the African Penguin (Spheniscus demersus) in Namibia. S. Afr. J. mar. Sci. 23: 429:434.

Ludynia K., Kemper J., Roux J-P. 2012 The Namibian Islands' Marine Protected Area: Using seabird tracking data to define boundaries and assess their adequacy. Biological Conservation 156: 136-145.

Ludynia K., Roux J-P., Jones R., Kemper J., Underhill, L.G. 2010. Surviving off junk: Low-energy prey dominates the diet of African penguins Spheniscus demersus at Mercury Island, Namibia, between 1996 and 2009. Afr. J. Mar. Sci. 32: 562-572.

Maartens L. 2003. Biodiversity (Chapter 7). Pp 103-133, in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Robertson T., Jarvis A., Mendelsohn J., Swart R. 2012. Namibia's Coast. Directorate of Environmental Affairs. Ministry of Environment and Tourism. Windhoek, Namibia.

Roux J-P. 2003. Risks (Chapter 8). Pp 137-152, in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Roux J-P., van der Lingen CD.,Gibbons MJ., Moroff NE., Shannon LJ., Smith AD., Cury PM. 2013. Jellyfication of marine ecosystems: Lessons from the Benguela. Bulletin of Marine Science 89: 249-284.

Simmons R.E., Brown C.J., and Kemper J. (Eds.) 2015 Birds to watch in Namibia: red, rare and endemic species. Ministry of Environment and Tourism and Namibia Nature Foundation, Windhoek.

Skov, H., Bloch, R., Lauridsen, F.S. and Uushona, D. 2010. Strategic Environmental Assessment (SEA) for the coastal areas of Namibia. Report for NACOMA. DHI report. 120 pp.

Zeybrandt F., Barnes J.I. 2001. Economic characteristics of demand in Namibia's marine recreational shore fishery. S. Afr. J. mar. Sci. 23: 145:156.

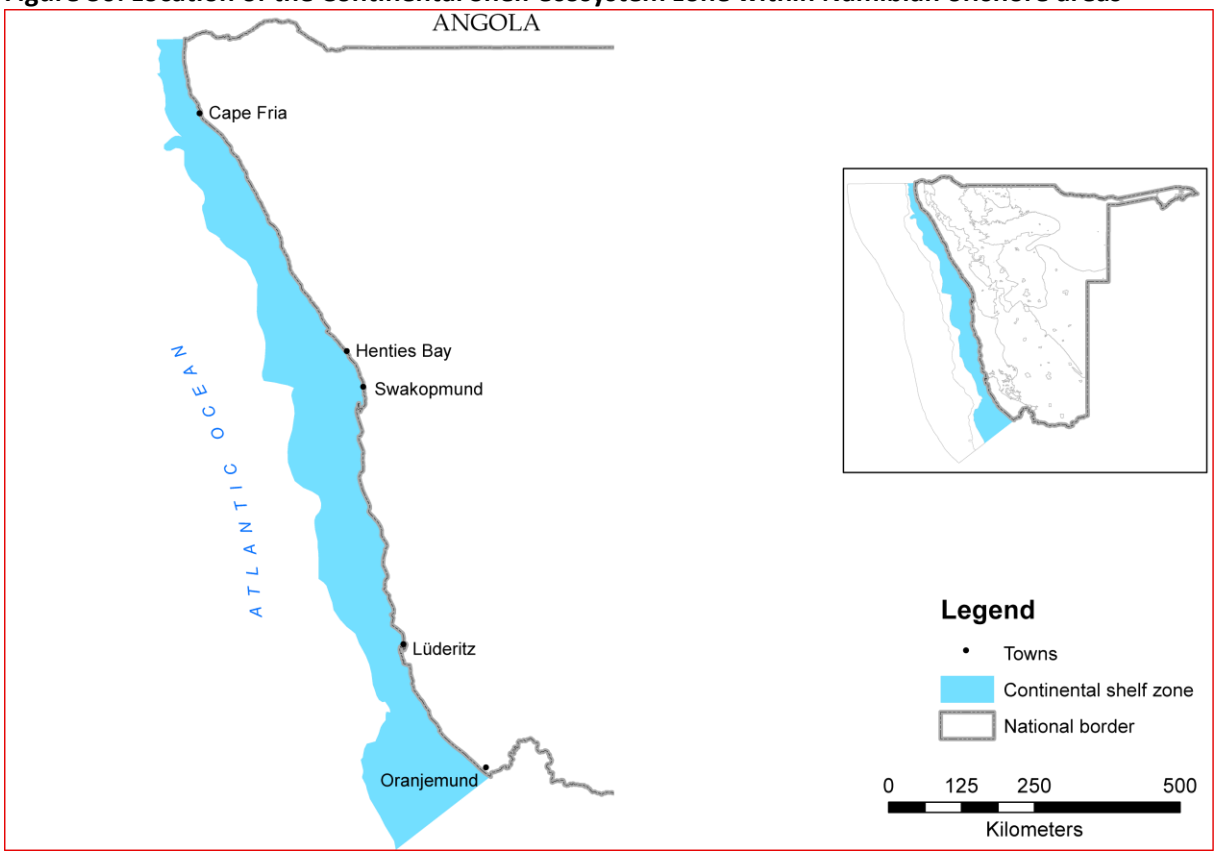
5.14 Continental Shelf

5.14.1 Description and assessment of ecosystem zone

5.14.1.1 Main attributes and ecological processes

The Continental Shelf represents the part of a continent that is submerged in relatively shallow sea, between the Coastal and Near-Shore and Shelf-Break and Slope zones. In Namibia, the depth of the sea in the Continental Shelf zone is between 30 m and 200/250 m, and its width ranges between 35 km and 150 km. It is depicted in Figure 30.

Figure 30: Location of the Continental Shelf ecosystem zone within Namibian offshore areas



The Namibian Continental Shelf is characterised by the north-moving Benguela current and intense wind-driven upwelling. The interplay between the position and strength of the South Atlantic Anticyclone, the shelf profile, the orientation of the coast and the seasonal changes in continental air pressure results in several upwelling cells along the coast. The water is therefore cool but extremely productive due to the nutrient enrichment from upwelled water.

The upwelling cell close to Lüderitz is the most intense in the world's oceans. This upwelling cell is active throughout the year but most intense in midsummer. It divides the Benguela region into two distinct pelagic ecosystems: the southern Benguela off the south and west coast of South Africa; and the Northern Benguela off Namibia which extends to the Angola-Benguela Front of southern Angola. These two sub-systems have discrete pelagic and semi pelagic fish stocks with very little exchange between them. The Lüderitz upwelling cell is the main source of marine nutrients for the whole

northern Benguela ecosystem, with the highest primary productivity occurring in the warmer and less turbulent central and north-central areas of the shelf.

The shelf is narrow in the extreme North (35 to 40 km north of Cape Fria) and widening progressively to the South along the Skeleton Coast, reaching its widest extent (about 150 km) in the central region off Walvis Bay. Further south, the shelf narrows again until it reaches the Orange River Cone, which constitutes a wide and relatively shallow fan of sediments with a very steep north-western margin. The narrow portion of the shelf at the edge of the Orange River Cone allows deep, cool and nutrient-rich water to be upwelled over the shelf by the Lüderitz upwelling cell.

In the central region of the Namibian shelf (the mud belt), large areas of the bottom are covered by fine muds of organic origin (linked to the high productivity of this area). These accumulations of organic sediment are in turn the cause of the low dissolved oxygen concentrations found near the bottom, as well as a unique community of anoxic bacterial mats on and in the sediments. Those mats are responsible for the production of hydrogen sulphide which accumulates in the sediment and occasionally erupts together with methane through the water column. These "sulphide eruptions" are toxic to most marine organisms and can cause mass mortalities of fish. Also linked to the extremely high productivity of the central shelf area in and around the "mud belt", some phosphate deposits occur on the sea floor in the central part of the shelf. Those deposits have been prospected but not mined commercially to date.

The Shelf ecosystem zone has previously sustained major pelagic fish stocks (sardine and anchovy in particular) and semi-pelagic species (like Cape horse mackerel) with extremely high biomass, as well as many other species of lesser economic importance (e.g. bearded goby). The shelf is also the habitat of the early life stages and juveniles of most other fish species found in the northern Benguela ecosystem including the most important commercial marine resource at present, hake.

The high fish biomass and productivity also sustained large populations of a diverse guild of predators. This included commercially exploited predatory fish species (for example Snoek and Albacore tuna); regionally endemic marine mammals and seabirds (e.g. African penguin, Cape gannet, Cape cormorant, Cape fur seal); other residents (such as Dusky dolphins and southern right whale dolphin); and many long distance migrants (particularly migrant seabirds from the North Atlantic as well as the Southern Ocean and Antarctica).

5.14.1.2 Human activity and population

The Namibian shelf is not open to trawling; only line fishing, lobster trapping on its inshore margin and purse seining. Shipping traffic over the shelf is not only linked to the two Namibian ports of Walvis Bay and Lüderitz, but also several shipping lanes that involve the export of oil and mineral deposits from Nigeria, Congo and Angola to the far east in particular. Traffic along these lanes has increased dramatically in recent decades.

Marine diamond mining is increasing in this zone and has the potential to expand further if the development of new technologies allows the bulk processing at sea of lower grade deposits which are not currently economically viable. This zone is also where the bulk marine mining of marine phosphate deposits is planned. The Namibian Islands' Marine Protected Area (NIMPA) is partially within this zone, as it extends into the inner shelf for about 400km around Lüderitz.

5.14.1.3 Pressures and drivers of change

Table 60: Broad drivers of change and ecosystem-specific pressures in the Continental Shelf ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Marine mining
Exploitation	Overexploitation of fish resources in this zone
Pollution	Pollution from industrialisation at the coast; shipping activity
Invasive species	No relevant pressures identified in this zone
Climate change	Modification of winds and currents, as well as a potential increase in inter-annual variability of upwelling
Illegal use	No relevant pressures identified in this zone

Table 60 relates the six broad categories of drivers of change to specific pressures within the Continental Shelf ecosystem zone. The main driver of change in the zone has been the overexploitation of small pelagic fish stocks (sardine and anchovy). This has had considerable further impacts on services in neighbouring ecosystem zones (see Sections 5.12.4 and 5.14.4).

Other pressures in the zone are currently relatively limited, although have the potential to grow in significance. The increasing trend in the volume of shipping activity over the Namibian shelf is a pressure on the marine ecosystem in various ways: increased risks of oil pollutions events, increased marine litter and (underwater) noise pollution, increased risk of collision with large cetaceans (southern right whales and humpback whales in particular). At the moment Namibia has not developed an effective oil pollution response plan, and at-sea surveillance (apart from that regarding fishing) is minimal, effectively allowing vessels to opportunistically discharge pollutants illegally along the shipping lanes. Industrialisation at the coast, including the processing of the seabed mining resources (diamonds and phosphate), has the potential to be detrimental to seawater quality beyond the coastal zone (through effluents in particular) and affect marine productivity further off the shelf.

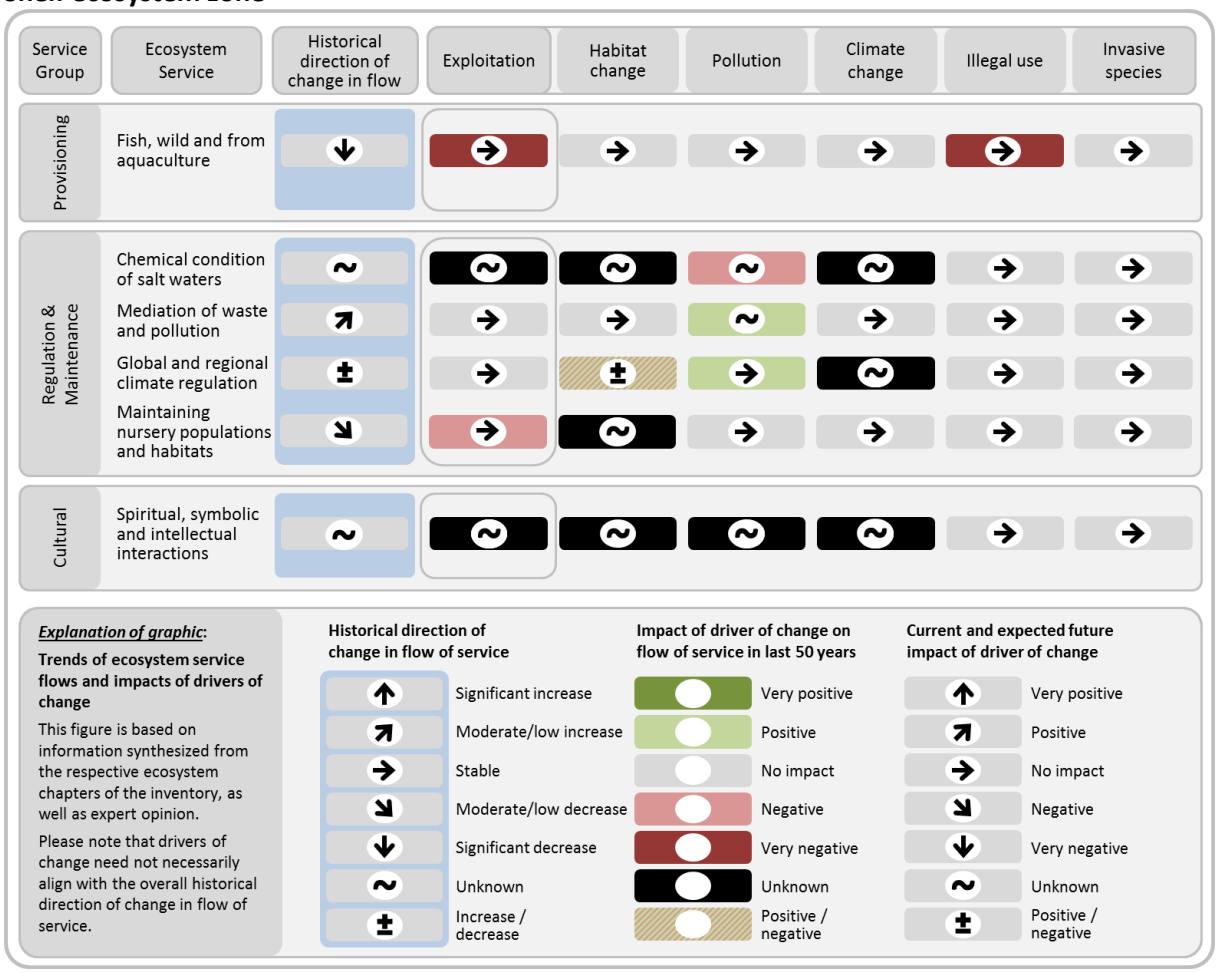
Climate change is thought to be a driver of change through the modification of winds and currents, as well as potentially increasing in the inter-annual variability of upwelling. This in turn could affect primary productivity and the retention and survival of fish eggs and larvae. The northern half of the Namibian shelf has experienced a significant increase in average sea surface temperature in the last three decades; however the effects of this on the ecosystem zone are at the moment poorly understood.

Marine mining on a large scale (as planned for the phosphate deposits in particular) will have significant impacts on the benthic habitat over the shelf as well as water quality through the water column; it will further increase turbidity and the remobilisation of chemicals from sediments (including hydrogen sulphide etc.). At present, the mining footprint is limited as it is constrained by the existing technologies for diamond mining. This footprint has the potential to increase considerably when new technologies are implemented and particularly if bulk seabed mining for phosphate is initiated. If it does, it will also likely result in increased pollution along the shelf.

5.14.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Continental Shelf ecosystem zone. Figure 31 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 31: Overview of flows of services and impacts from drivers of change in the Continental Shelf ecosystem zone



5.14.2.1 Provisioning

Table 61 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Continental Shelf (and which are comparable to those classes specified in Figure 31). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 61: Overview of provisioning services in the Continental Shelf ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Wild animals and their outputs	Small pelagic fish such as sardine	International	Consumptive use

Description

The only provisioning service derived from the Continental Shelf is the production of food from pelagic fish such as juvenile horse mackerel, sardine and, to a lesser extent, anchovy.

Affected population

Namibian pelagic fish and their products (like fish meal) are exported internationally. The processing of pelagic fish has also been an important part of local economies in Walvis Bay and Lüderitz.

Change in flow over past 50 years

Sardine biomass was estimated to have fluctuated between 4 and 11 million tons in the 1950s and early 1960s, but catches increased rapidly during the period from 1964 to 1971, and consequently as a result of overfishing (both legal and, prior to independence, poorly regulated) the stock biomass declined to just 10% of its previous size. By 1978, the stock and fishery had collapsed, and by 1980, 8 of the 11 canneries had closed down (accompanied by several thousand job losses). A purse-seine fishery targeting mainly anchovy and juvenile horse mackerel continued to operate, but stocks of anchovy crashed to insignificant levels by the late 1980s.

Despite calls for a moratorium on sardine fishing as early as 1982 to allow the stock (and the industry) to recover, the fishery was never closed. Consequently, the annual sardine landings declined from an average of 750,000 tons in the 1960s to less than 20,000 tons since the beginning of the 21st century, while anchovy catches declined from 200,000 tons in the late 1970s to less than 5,000 tons in recent years. Despite Namibia being a signatory of the 2002 World Summit on Sustainable Development (WSSD) treaty, which calls for urgent actions to allow depleted fish stocks to recover to productive levels, quotas for sardine are still given annually. Total small pelagic fish stocks are estimated to have declined from more than 12 million tons per annum during their peak to between 100,000 and 350,000 tons at present.

Pressures and expected impacts on flow of service

No change in the current level of this provisioning service is expected because the small pelagic fish stocks are at such low levels, and quotas for sardine are still given annually. Catches are much lower than they could be if the stock was at its peak level and being managed sustainably.

5.14.2.2 Regulation and maintenance

Table 62 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Continental Shelf.

Table 62: Overview of regulation and maintenance services in the Continental Shelf ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Bio-remediation by micro-organisms, algae, plants, and animals	Waste water cleaning/degrading oil spills	Regional	Indirect use
Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	Absorption of pollutants	Regional	Indirect use
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of pollutants	Regional	Indirect use
Mediation of smell/noise/visual impacts	Mediation of marine litter	Regional	Indirect use
Maintaining nursery populations and habitats	Nursery habitat for hake, sea birds	National	Indirect use
Chemical condition of salt waters	Maintenance of condition; Lüderitz upwelling cell	National	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Climate regulation	Regional	Indirect use

Description

Regulation and maintenance services occurring in the Continental Shelf relate to two divisions. The mediation of waste, toxins and other nuisances happens both at the level of the biota, which assist with waste water cleaning and degrading oil spills as well as absorbing pollutants, and at the level of the ecosystem zone which also works to absorb and dilute pollutants.

Relevant services within the division of the maintenance of physical, chemical and biological conditions relate to maintaining the nursery habitat for hake, maintaining the chemical condition of the sea water and climate regulation at both a global level, through carbon sequestration, as well as at micro and regional levels. The Lüderitz upwelling cell in particular is crucial for maintaining the chemical condition and therefore the nutrient levels of the water in the Continental Shelf, as well as that of neighbouring zones, and is the driver of its high productivity.

Affected population

The services relating to the mediation of waste, toxins and other nuisances are primarily relevant at a regional level, as they also impact on neighbouring ecosystem zones; the same goes for micro and regional climate regulation. There is likely to be minimal direct impact on human populations from these services, however.

Maintaining the nursery habitat for hake and the maintenance of the chemical condition of the Continental Shelf are of relevance nationally as these (at least have the potential to) support fairly significant numbers of jobs in Namibia through the fishing industry. Carbon sequestration is important to the global population to the extent that it affects global climate change.

Change in flow over past 50 years

It is thought that the flow of services such as waste water cleaning and the absorption and dilution of pollutants have increased over the past 50 years as a result of increased human activity and pollution in the Continental Shelf ecosystem zone. There is a considerable degree of uncertainty about the scale of these changes, however.

The nursery habitat quality for hake has declined quite significantly as a result of the overexploitation of the small pelagic stocks. The diet of the juvenile hake has become less energy dense (by between 20% and 25%) and cannibalism is thought to have increased. This has rendered the hake stock considerably less productive.

Carbon sequestration is estimated to have increased as a result of increased global carbon emissions, while any changes in micro and regional climate regulation are not well understood. Pollution may have decreased the chemical condition of the sea water in the Continental Shelf, but whether overexploitation of the small pelagic fish stocks or other pressures such as habitat and climate change have impacted on the Lüderitz upwelling cell is unknown.

Pressures and expected impacts on flow of service

There is expected to be increased shipping activity along the shelf, representing a pressure in terms of the increased risks of oil pollution events, marine litter, noise pollution and collisions with large cetaceans; this increase could be even greater if industries relating to offshore hydrocarbons and seabed mining expand. Whether this increased shipping activity will decrease the capacity of the ecosystem zone to mediate these pollutants and risks is unknown. Carbon sequestration in the Continental Shelf is likely to continue increasing as carbon emissions increase; however the capacity of the ecosystem zone to continue providing the service, and the effects of climate change, are unclear.

The expected future impacts on the flows of the other regulation and maintenance services are also largely uncertain. The condition of the nursery habitat for hake depends on whether the local habitat for the juveniles has been impacted in the long term as a result of the overexploitation of the small pelagic fish stocks; the same goes for the maintenance of the condition of the sea water and the Lüderitz upwelling cell, which may also be affected by climate change. There are also threats to the benthic habitat from seabed mining, which could negatively impact the delivery of these services.

5.14.2.3 Cultural

Table 63 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Continental Shelf.

Table 63: Overview of cultural services in the Continental Shelf ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Scientific	Research	International	Non-consumptive use
Educational	Education on marine environment	National	Non-consumptive use
Existence	Relating to marine environment and species	International	Existence
Bequest	Relating to marine environment and species	International	Bequest

Description

Cultural services relating to the Continental Shelf are primarily based around scientific research, marine education and existence and bequest services derived from the marine environment and the species within them. There are few if any recreational activities that take place within the zone.

Affected population

The research, existence and bequest services are relevant to international populations due to the importance the importance of this zone as one of the most productive marine areas in the world supporting many species of regional as well as global importance. Education around the marine environment is important nationally.

Change in flow over past 50 years

Research and education services are thought to have increased over the past 50 years as a result of increased human activity and interest in these areas, and particularly following independence. Existence and bequest services, and what affects them, are generally not well understood.

Pressures and expected impacts on flow of service

It is generally unclear what impacts the different pressures will have on the flow of these cultural services. As an example, the overexploitation of the small pelagic fish stocks may open up research in different areas than if the stock had been managed sustainably.

5.14.2.4 Interactions between ecosystem zones and ecosystem services

The sardine held a crucial ecological position in the food web as the largest consumers of primary and secondary production (phyto- and zooplankton), in addition to being the main link between producers and high trophic levels (including piscivorous fish such as hake, marine mammals and seabirds as well as humans). As the small pelagic fish stocks have been virtually removed and have not recovered, this link in the food web has been effectively missing for the last four decades.

The removal of the sardines also inhibits measures like the Namibian Islands' Marine Protected Area (NIMPA) to effectively preserve the juveniles of the hake stocks and their habitat. Prohibiting trawling in the Continental Shelf to protect the juveniles is not expected to bear fruit until the

sardine stock has recovered substantially, as at present the remaining sardine has a limited distribution far to the north of NIMPA.

The impact on upper-trophic level organisms has been primarily realised through significant reduction in populations of many regionally endemic seabirds (for example African penguin have fallen by more than 75%, Cape cormorant by more than half and Cape gannet more than 90%), and are now at serious risk of extinction. As the diet quality of the juvenile Cape hake has degraded, the hake stock has becomes significantly less productive.

At lower trophic levels, the 'unused production' which the small pelagic stocks previously consumed contributes to the detritus accumulation in the sediments, and hence to the detrimental hypoxic condition near the bottom. Jellyfish have become the main zooplankton consumers and their biomass has increased, but they contribute very little to the energy transfers upwards in the food web.

Consequently the overexploitation of the pelagic fish stocks has also negatively affected the stock and value of other fish resources (such as hake which is fished in the Shelf-Break and Slope zone), the guano industry (Coastal and Near-Shore zone) and biodiversity (likely affecting tourism in the Coastal and Near-Shore zone, as well as the general functioning of the Continental Shelf and its neighbouring ecosystem zones). Coastal economies have been significantly adversely affected by the loss of fishing and processing industries.

Indeed, the removal of the pelagic stocks has had drastic consequences on the Namibian marine ecosystem as a whole. The Northern Benguela ecosystem has been qualified as "dysfunctional" and "degraded"; it is at present the only eastern boundary upwelling ecosystem in the world without a large biomass of small pelagic fishes.

5.14.3 Criteria for prioritisation of ecosystem services

5.14.3.1 Current and future expected impacts on the flow of the service

The services under the greatest threats are the chemical condition of the water (from increased pollution and seabed mining in particular) and long term effects on the Benguela upwelling system itself and the (potential) productivity it supports. The small pelagic fish stocks have already been severely depleted. As these are a key link in the food web, this could be compromising biodiversity.

5.14.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

There are no relevant threats from unsustainable water uses in this ecosystem zone.

Expansion of urban areas and increasing industrialisation

Increasing industrialisation at the coast could increase pollution and reduce water quality in the Continental Shelf zone.

Threats and impacts of climate change

Climate change could impact on the Benguela upwelling system, but any effects are not presently well understood.

Rapid expansion of mining and prospecting

Seabed mining represents a threat to the marine habitat and the fish species and their juveniles in the zone; it could also threaten water quality.

Unsustainable land management practices

There are no relevant threats in this ecosystem zone.

Uncontrolled bush fires

There are no relevant threats in this ecosystem zone.

Alien invasive species

There are no relevant threats in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

There are no relevant threats in this ecosystem zone.

Human-wildlife conflict

Increased shipping activity is likely to increase the risk of collisions with large cetaceans.

5.14.3.3 Economic importance (current and potential)

The restoration of the small pelagic fish stocks could represent a significant contributor to the Namibian economy; not only in terms of revenue and onshore processing directly supported by the activity, but also through its effects on other valuable fish stocks (e.g. hake) and additional activities such as guano harvesting and tourism activities related to biodiversity.

5.14.3.4 Affected population (size and socio-economic characteristics)

The restoration of the small pelagic fish stocks could support a large number of jobs in coastal towns that have suffered as a result of their decline, as well as a major contributor to food security in the region.

5.14.3.5 Availability of data and valuation methods

Data estimates should be available for stocks of small pelagic fish, but their contribution to wider services in this and neighbouring ecosystem zones is not fully understood. Research conducted by the Ministry of Fisheries and Marine Resources (MFMR), the Benguela Current Commission and institutes such as SANUMARC are important sources of data.

5.14.4 References

Benguela Current Commission. 2011. Annual State of Fish Stocks Reports. Benguela Current Large Marine Ecosystem, 2nd Edition, 91 pp. BCC, Windhoek, Namibia.

Boyer D.C., Hampton I. 2001. An overview of the living marine resources of Namibia. S. Afr. J. mar. Sci. 23: 5-35.

Hampton I. 2003. Harvesting the sea (Chapter 5). Pp 31-69 in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Ludynia K., Roux J-P., Jones R., Kemper J., Underhill, L.G. 2010. Surviving off junk: Low-energy prey dominates the diet of African penguins Spheniscus demersus at Mercury Island, Namibia, between 1996 and 2009. Afr. J. Mar. Sci. 32: 562-572.

Maartens L. 2003. Biodiversity (Chapter 7). Pp 103-133, in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Roux J-P. 2003. Risks (Chapter 8). Pp 137-152, in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Roux J-P., Shannon L.J. 2004. Ecosystem approach to fisheries management in the Northern Benguela: The Namibian experience. Afr. J. mar. Sci. 26: 79-93

Roux J-P., van der Lingen CD.,Gibbons MJ., Moroff NE., Shannon LJ., Smith AD., Cury PM. 2013. Jellyfication of marine ecosystems: Lessons from the Benguela. Bulletin of Marine Science 89: 249-284.

Shannon L., Coll M., Neira S., Cury P., Roux J-P. 2009. Impacts of fishing and climate change explored using trophic models. Chapt. 8. Pp 158-190 in: Climate change and small pelagic fish. (D. Checkley, C. Roy, J. Alheit and Y. Oozebi Eds). Cambridge University Press.

Simmons R.E., Brown C.J., and Kemper J. (Eds.) 2015 Birds to watch in Namibia: red, rare and endemic species. Ministry of Environment and Tourism and Namibia Nature Foundation, Windhoek.

van der Lingen C.D., Shannon, L.J., Cury P., Kreiner A., Moloney C.L., Roux J-P., Vaz-Velho F. 2006. Resource and ecosystem variability, including regime shifts. Pp. 147-184 in: The Benguela: Predicting a Large Marine Ecosystem. Large Marine Ecosystem Series Vol.14., V. Shannon, G. Hempel, P. Manalotte-Rizzoli, C. Moloney and J. Woods Eds. Elsevier.

Watermeyer K.E., Shannon L.J., Roux J-P., Griffiths C.L. 2008. Changes in the trophic structure of the northern Benguela before and after the onset of industrial fishing. Afr. J. Mar. Sci. 30 (2): 383-403.

Wilhelm MR, Kirchner CH, Roux J-P, Jarre A., Iitembu JA, Kathena JN, Kainge P. 2015. Chapt. 3. Biology and fisheries of the shallow water hake (Merluccius capensis) and the deep-water hake (Merluccius paradoxus) in Namibia. Pp 70-100. In: Arancibia H (ed.), Hakes, Biology and Exploitation; Wiley-Blackwell Science – Fish and Aquatic Resources Series 17.

Wilhelm MR, Roux J-P, Moloney CL, Jarre A. 2013. Data from fur seal scats reveal when Namibian Merluccius capensis are hatched and how fast they grow. ICES J Mar Sci. 70 (7): 1429-1438.

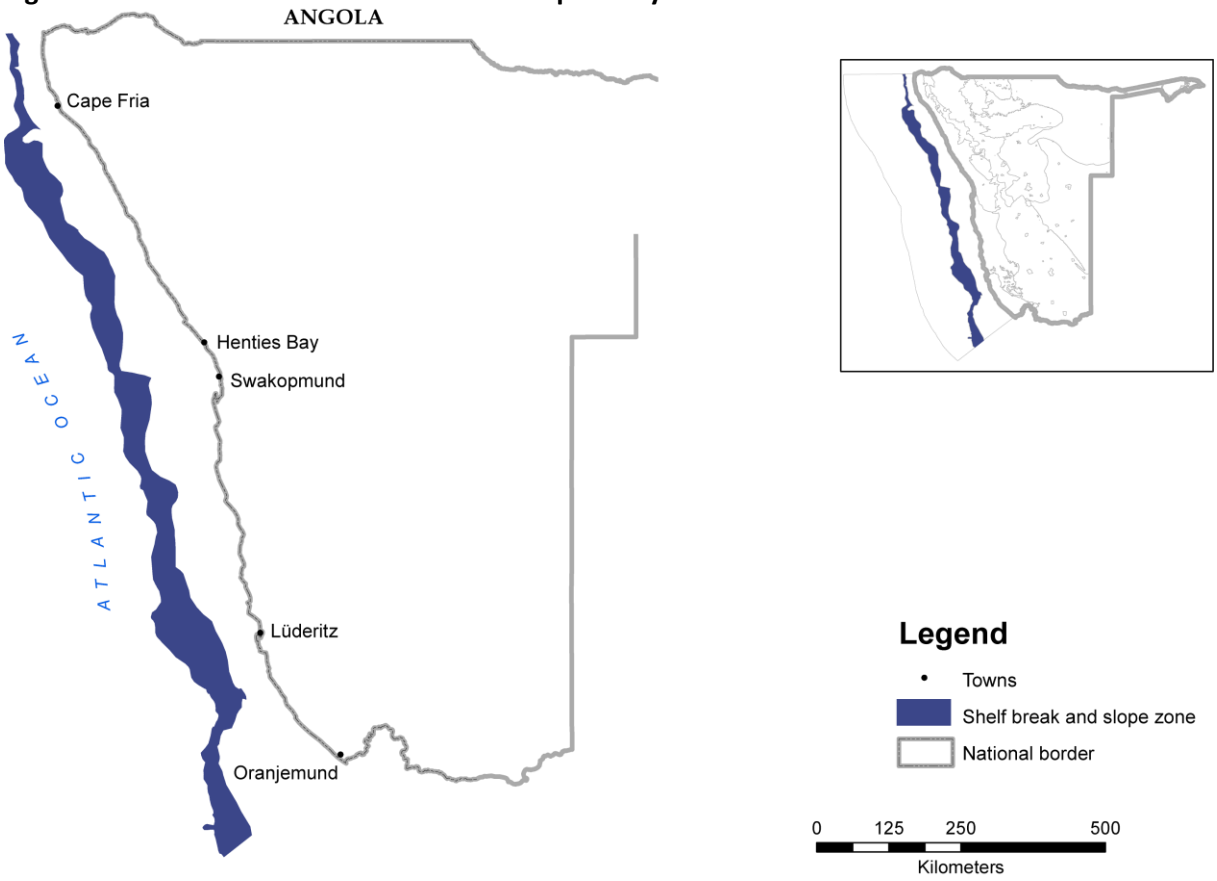
5.15 Shelf-Break and Slope

5.15.1 Description and assessment of ecosystem zone

5.15.1.1 Main attributes and ecological processes

The Shelf-Break and Slope zone marks a distinct change in the depth of the Atlantic ocean off of Namibia as it transitions from the relatively shallow (200/250 m) edge of the Continental Shelf to the lower shelf slope at about 700 m in depth. It is mapped in Figure 32.

Figure 32: Location of the Shelf-Break and Slope ecosystem zone within Namibian offshore areas



The zone is typical of Continental Shelf margins, with a pronounced slope from the shelf break towards the abyssal plains below. The shelf break is between 300 m and 350 m off most of Namibia, which is relatively deep compared to the world average of around 130 m. The cool, nutrient-rich upwelled water extends over this zone from the Continental Shelf and forms a convoluted and variable frontal zone with the adjacent warmer oceanic water usually well offshore.

This frontal zone often features surface filaments of upwelled Benguela water far offshore and may be the site of episodic jet currents. The nature and functioning of this offshore boundary of the Benguela system is quite complex and at present poorly understood. At depth there is a deep counter current frequently bringing oxygen-depleted water southwards from the region of the Angola dome.

Although this zone is relatively small in area, it contains essential habitats for the main trawl fish resources which constitute the bulk of the Namibian fishing industry at present, both in volume and

in value. Most of these demersal and semi-demersal species have habitat preferences depending on depth: the shelf break (200-300 m) is the preferred habitat for horse mackerel, medium size hakes and west coast sole; the upper slope (300-400 m) is dominated by shallow-water Cape hake, monkfish, kingklip, and lanternfish along with other mesopelagic forage species; and deeper on the slope (400-600 m) the deep-water Cape hake becomes dominant species, accompanied by a suite of deep water species.

There is also a latitudinal gradient in species distributions in the zone. While the two hake species (at commercial sizes) are found along the entire length of the zone, several species characteristic of the Southern Benguela reach their northernmost distribution in the vicinity of Lüderitz (accounting for the higher demersal fish biodiversity in the southern region). The northern region contains most of the horse mackerel resource and its spawning ground, as well as a number of species more characteristic to the Angolan region which reach their southernmost distributions north of Walvis Bay.

5.15.1.2 Human activity and population

There are no protected areas in this zone which is therefore entirely open to fisheries; these are primarily bottom and mid-water trawl types, as well as some Japanese–style beehive traps (for crab). Like in the Continental Shelf zone, extensive prospecting for hydrocarbon deposits has intensified in the last decade with extensive seismic surveys. To date no economically viable deposits have been detected. In the central region of this zone on the upper part of the slope, several prospecting mining licences (EPLs) have been granted for possible large scale mining of marine phosphate.

5.15.1.3 Pressures and drivers of change

Table 64: Broad drivers of change and ecosystem-specific pressures in the Shelf-Break and Slope ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Ground gear and seabed mining; incidental mortality of seabirds from trawling and long-lining
Exploitation	Exploitation and overexploitation of fish resources in this zone and along the shelf
Pollution	No relevant pressures identified in this zone
Invasive species	No relevant pressures identified in this zone
Climate change	Modification of winds and currents, as well as a potential increase in inter-annual variability of upwelling
Illegal use	Illegal fishing prior to independence

Table 64 relates the six broad categories of drivers of change to specific pressures within the Shelf-Break and Slope ecosystem zone. As in the Continental Shelf ecosystem zone, the main driver of change in the zone has been the overexploitation of small pelagic fish stocks (sardine and anchovy) along the shelf. This is thought to have had impacts on the dynamics of important fish stocks (such as Cape hake). Furthermore, the Cape hake stocks, along with horse mackerel, may have also been overexploited prior to Independence.

Fisheries in the zone are to an extent in competition with each other due to bycatch of non-target species (e.g. hake being caught as bycatch in the horse mackerel fishery, monk fish as bycatch in the hake fishery etc); this further complicates the implementation of quota limits and the assessment of total fishing mortality for each stock. A discard ban was instituted a decade ago but problems persist.

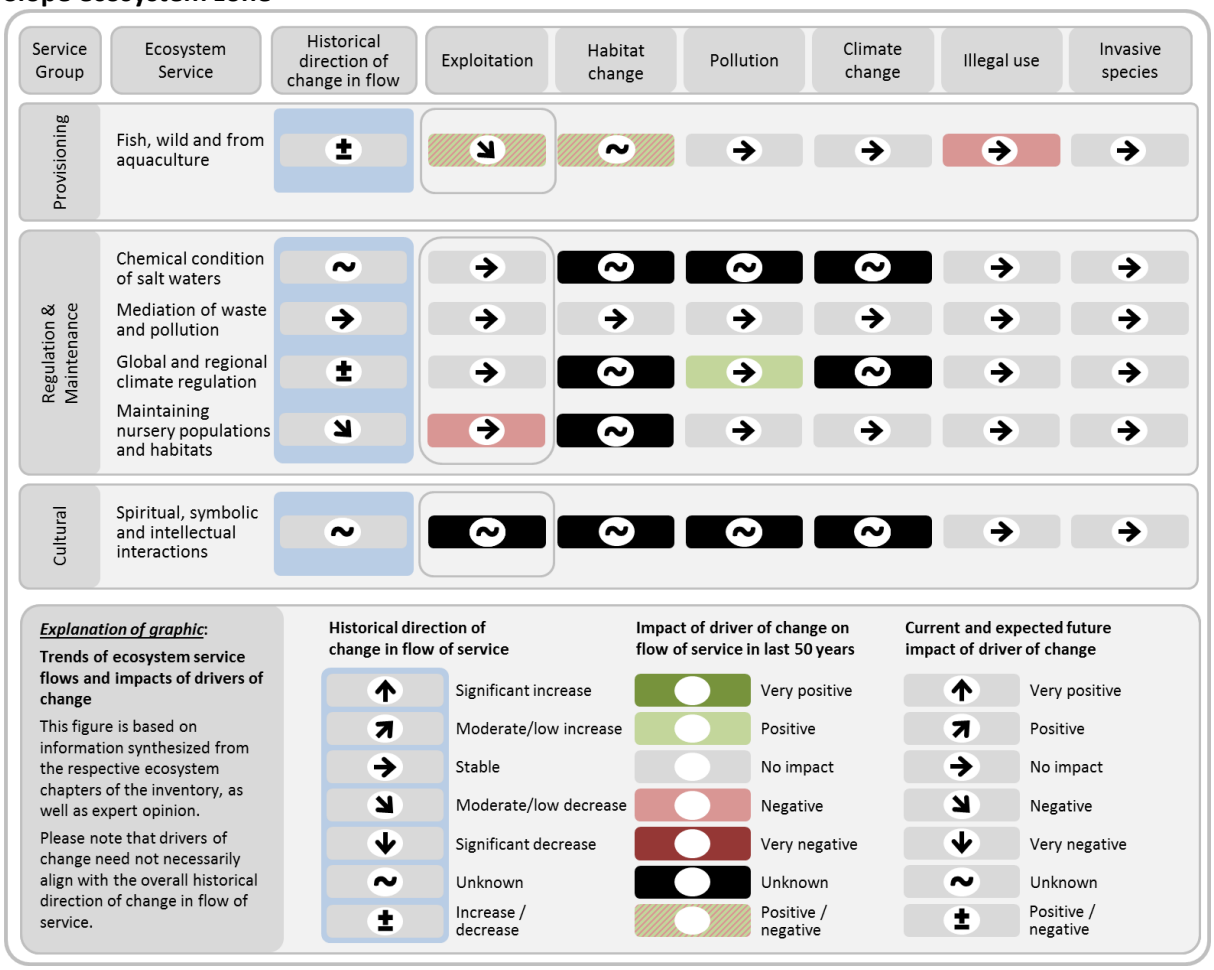
Trawling and long-lining in the zone are a severe cause of mortality of seabirds (mostly migrant seabirds of conservation concern, like endangered species of petrels and albatrosses). As a result of the collapse of the small pelagic stocks on the shelf, the Cape gannet is also affected as discards from the trawl industry represent a substitute food source; the Cape gannet is now critically endangered in Namibia. Although there is considerable uncertainty around the effects of Deep Seabed mining as it has not been conducted on a large scale anywhere in the world, a consensus is emerging that it is likely to have significant impacts on fish stocks, their habitats, water quality and fishing operations themselves.

Climate change is thought to be a driver of change through the modification of the winds and currents, as well as a potential increase in the inter-annual variability of upwelling, which in turn affects primary productivity and retention and survival of fish eggs and larvae. Although the possible effects on this zone are not well understood or investigated at the moment, it is believed that changes in the deep undercurrent bringing hypoxic waters in this zone could have severe impacts of the demersal fish stocks.

5.15.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Shelf-Break and Slope ecosystem zone. Figure 33 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 33: Overview of flows of services and impacts from drivers of change in the Shelf-Break and Slope ecosystem zone



5.15.2.1 Provisioning

Table 65 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Shelf-Break and Slope zone (and which are comparable to those classes specified in Figure 33). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 65: Overview of provisioning services in the Shelf-Break and Slope ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Wild animals and their outputs	Hake, monk fish, west coast sole, horse mackerel and deep-sea red crab	International	Consumptive use

Description

A number of species of fish are caught in the Shelf-Break and Slope zone for the production of food. There are two bottom-trawl fisheries in operation: one targeting hake and the other monk fish and west coast sole. The two are in competition however as the much larger hake fishery catches monk fish and sole, alongside kingklip and horse mackerel, as bycatch. The other two fisheries are a mid-water trawl fishery targeting horse mackerel and Japanese-style beehive traps used to catch deep-sea red crab.

Affected population

All fisheries export at least some of their catch, and so the relevant population is international. There has been an increasing trend to process the catch of the trawl fisheries onshore, particularly so with regard to the hake-targeting fishery: around the time of independence approximately 90% of the hake catch was processed on board or after export, while now around two-thirds is processed onshore; consequently it represents an important economic activity for coastal towns. The deep-sea red crab fishery on the other hand has little socio-economic impact on coastal towns as catches are generally processed on-board.

Change in flow over past 50 years

The bottom-trawl fishery targeting hakes started in Namibia in the mid-1960s and rapidly developed as a long-distance fishery operated by various nations with no or little control, resulting in illegal fishing and the overexploitation of the stock. Catches increased to a peak of more than 800 thousand tons in 1972 but started declining rapidly thereafter. At the time of independence in 1990 those stocks were severely depleted.

In 1990, Namibia took control of its 200 nautical mile EEZ (Exclusive Economic Zone), curbed illegal fishing and implemented management measures to control the fishery and rebuild the depleted hake stocks. However, the hake stocks have not shown the expected rebuilding and remain today at approximately the 1990 levels and with average annual yields of around 135 thousand tons since independence.

It is believed today that the deep-water hake fished in Namibia is an extension of the southern Benguela stock and does not spawn locally. The Cape hake on the other hand is a separate stock with spawning grounds along the shelf and nursery areas over the shelf. The ecological changes triggered by the collapse of the sardine and anchovy stocks may have reduced the productivity of this valuable species through reduced recruitment, and that could have contributed to the non-recovery of this stock. In addition, it seems that the stock assessment procedure for hake since independence (based on an age-structured production model) has incorporated several erroneous assumptions (particularly regarding growth rates and catch at age) resulting in a poor understanding of the dynamic of the stock and, therefore, possibly inadequate scientific advice for management (and consequently overfishing).

Despite being far from its optimal level, this fishery is still the most valuable in Namibia. It constitutes the bulk of fisheries export earnings, which in turn accounted for as much as 20% of all Namibian exports in the mid-1990s.

The mid-water horse mackerel trawl fishery also greatly intensified in the 1970s, with catches increasing from around 50,000 tons to nearly 600,000 tons in the early 1980s. Since then, annual catches of horse mackerel have declined steadily to an average of 260,000 tons since the mid-1990s, which makes it the largest fishery by volume in Namibian waters, but is of relatively low market value. The decline in the stock has been accompanied by signs that it might be under stress as a result of overexploitation, with a reduction in the size of the fish and a decline in the known spawning grounds.

The deep-sea red crab stock has also been overexploited; catches peaked at over 10,000 tons in 1983, but current catches are around 2,000 to 3,000 tons. While it is a low volume fishery, the products are of high value: in 2000, the export value of crab products was around N$35m.

The monk fish and west coast sole fishery has seen increased catches as a result of increased quotas in recent years, growing from around 6,000 tons in the mid-2000s to 12,000 in 2014. Monkfish are a high value species, and is an important contributor to the Namibian economy: the landed value was greater than N$100m in 2000.

Pressures and expected impacts on flow of service

Exploitation of the hake and deep-sea red crab stocks is unlikely to change from current levels, having previously been overfished. The deep-sea red crab stock seems stable at present and it is hoped that new management strategies based on a better understanding of the dynamics of the hake stocks could contribute to their future recovery. Signs that the horse mackerel stock is under stress indicate that it could still be being overexploited, and could lead to reduced stocks and consequently catches in the future. The growth in the exploitation of monkfish and west coast sole in recent years could represent some degree of overexploitation, as quotas were above recommended levels for total allowable catch (TAC), and quotas have started being reduced. Catches of monkfish are expected to decline slightly from their present levels in coming years.

There is also growing concern about the potential effects of the planned seabed mining for phosphate on the habitats and consequently the stocks of these fish resources, but given that Deep Seabed mining has not been conducted at a large scale anywhere in the world, these effects are still largely uncertain. Ground gear such as bottom trawls and trawl doors may also be having a detrimental effect on the sea floor habitats, but these impacts are also uncertain and of less concern.

Climate change is thought to effect the modification of winds and currents, as well as potentially increasing the inter-annual variability of upwelling; this could in turn affect primary productivity and the survival of fish eggs and larvae. Any changes in the deep undercurrent bringing hypoxic waters in this zone could also have severe negative impacts on the demersal fish stocks, but the effect of climate change in this regard is not well understood.

5.15.2.2 Regulation and maintenance

Table 66 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Shelf-Break and Slope zone.

Table 66: Overview of regulation and maintenance services in the Shelf-Break and Slope Zone ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Bio-remediation by micro-organisms, algae, plants, and animals	Waste water cleaning/degrading oil spills	Regional	Indirect use
Filtration/sequestration/storage/ accumulation by micro-organisms, algae, plants, and animals	Absorption of pollutants	Regional	Indirect use
Filtration/sequestration/storage/ accumulation by ecosystems	Absorption of pollutants	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of pollutants	Regional	Indirect use
Maintaining nursery populations and habitats	Nursery habitat for horse mackerel and other commercial species; seabird feeding habitat	National	Indirect use
Chemical condition of salt waters	Maintenance of condition	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Climate regulation	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances happens both at the level of the biota, which assist with waste water cleaning and degrading oil spills as well as absorbing pollutants, and at the level of the ecosystem which also works to absorb and dilute pollutants. The maintenance of physical chemical and biological conditions relate to maintaining the nursery habitat for horse mackerel, maintaining seabird feeding habitats, maintaining the chemical condition of sea water and climate regulation at both a global level, through carbon sequestration, as well as at micro and regional levels.

Affected population

The services relating to the mediation of waste, toxins and other nuisances are primarily relevant at a regional level, as they also impact on neighbouring ecosystem zones; the same goes for micro and regional climate regulation. There is likely to be minimal direct impact on human populations from these services, however.

Maintaining nursery habitats for the important fish stocks targeted by the trawl fishery in particular is of particular relevance nationally as a major contributor to the economy, jobs in coastal towns as well as food production, while seabirds are crucial for the guano industry as well as tourism. Carbon sequestration is important to the global population to the extent that it affects global climate change.

Change in flow over past 50 years

There is not thought to have been much change in the flow of services relating to the mediation of waste, toxins and other nuisances as there are limited pressures resulting from pollution in the zone. The effects on the maintenance of the condition of the sea water are unknown, as there may be some knock-on impacts from the removal of the pelagic fish stocks in the Continental Shelf zone, but generally it is thought to be fairly stable. Carbon sequestration is estimated to have increased as a result of increased global carbon emissions, while any changes in micro and regional climate regulation are not well understood.

The nursery habitat for horse mackerel and the seabird feeding habitats have been negatively impacted in recent decades. The former has shown signs of stress, possibly as a result of overexploitation, which could further limit catches in the future. Increased trawling and long-lining in the zone are a severe cause of mortality of seabirds (mostly migrant seabirds of conservation concern, like endangered species of petrels and albatrosses, but also the Cape gannet following the collapse of the small pelagic stocks on the shelf).

Pressures and expected impacts on flow of service

No significant pressures surrounding pollution are anticipated, so limited change in the flow of these services is expected. The ongoing effects on sea water quality in the zone, as well as any impacts on climate regulation, are not well understood. Carbon sequestration is likely to continue increasing as carbon emissions increase; however the capacity of the ecosystem zone to continue providing the service, and the effects of climate change, are unclear.

The expected future effects on the habitats of the main fisheries species are also uncertain; this is largely due to diverse potential medium to long term effects from a variety of different pressures (from management strategies of the resources themselves to the effects of proposed seabed mining on the habitats). A reduction in the mortality of seabirds is expected as a result of the implementation of mitigation measures such as Tori lines.

5.15.2.3 Cultural

Table 67 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Shelf-Break and Slope zone.

Table 67: Overview of cultural services in the Shelf-Break and Slope ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Scientific	Research	International	Non-consumptive use
Educational	Education on marine environment	National	Non-consumptive use
Existence	Relating to marine environment and species	International	Existence
Bequest	Relating to marine environment and species	International	Bequest

Description

Cultural services relating to the Shelf-Break and Slope zone are primarily based around scientific research, marine education and existence and bequest services derived from the marine environment and the species within them. There are few if any recreational activities that take place within the zone.

Affected population

The research, existence and bequest services are relevant to international populations due to the importance of the species within the ecosystem zone. Education around the marine environment is important nationally.

Change in flow over past 50 years

Research and education services are thought to have increased over the past 50 years as a result of increased human activity and interest in these areas, and particularly following independence. Existence and bequest services, and what affects them, are generally not well understood.

Pressures and expected impacts on flow of service

It is generally unclear what impacts the different pressures will have on the flow of these cultural services.

5.15.2.4 Interactions between ecosystem zones and ecosystem services

The collapse of the small pelagic fish stocks in the Continental Shelf zone is thought to have reduced the productivity of the hake stocks through reduced recruitment as discussed in Section 5.13.4), which could in turn have contributed to the non-recovery of the stock. The bottom and mid-water trawl fisheries in this zone are in competition with each other, as the hake fishery catches monkfish and west coast sole as bycatch, and the relatively low selectivity of the large mid-water trawls used in the horse mackerel has raised concerns about the potential high bycatch of other species (including hake). The horse mackerel fishery is also in competition with the near-shore purse-seine fishery which targets the juveniles of the same species for fish meal.

Trawling and long-lining in the zone has a severe impact on the mortality of seabirds. This is in turn having effects on the guano industry which is harvested in the Coastal and Near-Shore zone, as well as on biodiversity. It could also threaten certain types of tourism.

5.15.3 Criteria for prioritisation of ecosystem services

5.15.3.1 Current and future expected impacts on the flow of the service

The services under the greatest threats are the chemical condition of the water (from increased pollution and seabed mining in particular) and the habitats of horse mackerel and seabirds. There are some mitigation measures being undertaken to reduce pressure on the latter.

5.15.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

There are no relevant threats from unsustainable water uses in this ecosystem zone.

Expansion of urban areas and increasing industrialisation

There are no relevant threats from unsustainable water uses in this ecosystem zone.

Threats and impacts of climate change

Climate change could impact on the Benguela upwelling system and consequently on the chemical condition of the water, but any effects are not presently well understood.

Rapid expansion of mining and prospecting

Seabed mining represents a threat to the marine habitat and the fish species and their juveniles in the zone; it could also threaten water quality.

Unsustainable land management practices

There are no relevant threats in this ecosystem zone.

Uncontrolled bush fires

There are no relevant threats in this ecosystem zone.

Alien invasive species

There are no relevant threats in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

There are no relevant threats in this ecosystem zone.

Human-wildlife conflict

Increased shipping activity is likely to increase the risk of collisions with large cetaceans, and Fishing in the zone is contributing to the mortality of endangered seabirds.

5.15.3.3 Economic importance (current and potential)

The hake stock is currently the most economically important fish resource in Namibia. It is operating at a level that is probably below what it could be if it (and other fish stocks, such as the small pelagic ones) had been managed optimally.

5.15.3.4 Affected population (size and socio-economic characteristics)

The fisheries (particularly the hake) contribute greatly to national and local economies; the hake processing factories at Lüderitz and Walvis Bay represent the main employers in those towns. .

5.15.3.5 Availability of data and valuation methods

Data estimates should be available for stocks of fish resources in this zone. Research conducted by the Ministry of Fisheries and Marine Resources (MFMR), the Benguela Current Commission and institutes such as SANUMARC are important sources of data.

5.15.4 References

Benguela Current Commission. 2011. Annual State of Fish Stocks Reports. Benguela Current Large Marine Ecosystem, 2nd Edition, 91 pp. BCC, Windhoek, Namibia.

Boyer D.C., Hampton I. 2001. An overview of the living marine resources of Namibia. S. Afr. J. mar. Sci. 23: 5-35.

Cury P.M., Shannon L.J., Roux J-P., Daskalov G.M., Jarre A., Moloney C.L., Pauly D. 2005.Trophodynamic indicators for an Ecosystem Approach to Fisheries. ICES J. Mar. Sci. 62: 430-442.

Hampton I. 2003. Harvesting the sea (Chapter 5). Pp 31-69 in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Maartens L. 2003. Biodiversity (Chapter 7). Pp 103-133, in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Roux J-P. 2003. Risks (Chapter 8). Pp 137-152, in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Roux J-P., Shannon L.J. 2004. Ecosystem approach to fisheries management in the Northern Benguela: The Namibian experience. Afr. J. mar. Sci. 26: 79-93

Roux J-P., van der Lingen CD.,Gibbons MJ., Moroff NE., Shannon LJ., Smith AD., Cury PM. 2013. Jellyfication of marine ecosystems: Lessons from the Benguela. Bulletin of Marine Science 89: 249-284.

Simmons R.E., Brown C.J., and Kemper J. (Eds.) 2015 Birds to watch in Namibia: red, rare and endemic species. Ministry of Environment and Tourism and Namibia Nature Foundation, Windhoek.

van der Lingen C.D., Shannon, L.J., Cury P., Kreiner A., Moloney C.L., Roux J-P., Vaz-Velho F. 2006. Resource and ecosystem variability, including regime shifts. Pp. 147-184 in: The Benguela: Predicting a Large Marine Ecosystem. Large Marine Ecosystem Series Vol.14., V. Shannon, G. Hempel, P. Manalotte-Rizzoli, C. Moloney and J. Woods Eds. Elsevier.

Van der Westhuizen A. 2001. A decade of exploitation and management of the Namibian hake stocks. S. Afr. J. mar. Sci. 23: 307:315.

Watermeyer K.E., Shannon L.J., Roux J-P., Griffiths C.L. 2008. Changes in the trophic structure of the northern Benguela before and after the onset of industrial fishing. Afr. J. Mar. Sci. 30 (2): 383-403.

Wilhelm MR, Kirchner CH, Roux J-P, Jarre A., Iitembu JA, Kathena JN, Kainge P. 2015. Chapt. 3. Biology and fisheries of the shallow water hake (Merluccius capensis) and the deep-water hake (Merluccius paradoxus) in Namibia. Pp 70-100. In: Arancibia H (ed.), Hakes, Biology and Exploitation; Wiley-Blackwell Science – Fish and Aquatic Resources Series 17.

Wilhelm MR, Roux J-P, Moloney CL, Jarre A. 2013. Data from fur seal scats reveal when Namibian Merluccius capensis are hatched and how fast they grow. ICES J Mar Sci. 70 (7): 1429-1438.

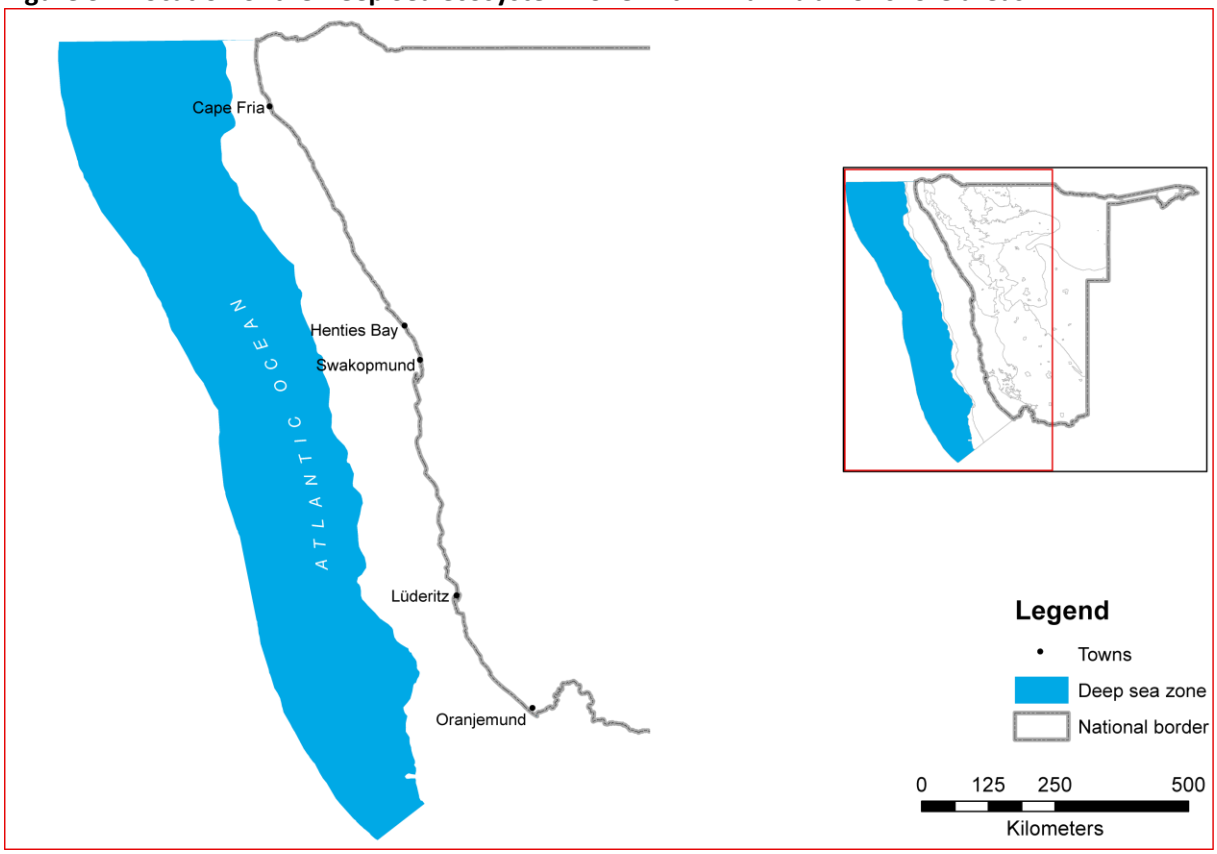
5.16 Deep Sea

5.16.1 Description and assessment of ecosystem zone

5.16.1.1 Main attributes and ecological processes

The Deep Sea ecosystem zone groups several habitats extending offshore from the Shelf-Break and Slope zone, including the lower shelf slope deeper than about 700 m down towards the abyssal plains at the limit of the Namibian Exclusive Economic Zone. Its extent is presented in Figure 34. The zone includes several seamounts which are important feeding areas for tuna-like species and as deep-sea biodiversity hotspots.

Figure 34: Location of the Deep Sea ecosystem zone within Namibian offshore areas



It is generally within this zone that the outer limit of the Benguela Current ecosystem is situated where cool, nutrient rich upwelled water meets warmer oceanic water. As one moves further offshore, the continental effect on surface atmospheric pressure gradients diminishes and the average wind speed declines, as a result there is less or no upwelling and less mixing and the water column in this zone is marked by a strong stratification with a well-defined thermocline. At the frontal zone itself there may be localized accumulation of nutrients and plankton providing feeding "hot spots" for oceanic migratory species like seabirds and tunas. This frontal zone also constitutes the western limit of most species endemic to the Benguela region from plankton to fish, seabirds and marine mammals.

Some of the demersal species found on the slope do have a distribution extending beyond 700 m depth (like the hakes) but generally at low density. The great majority of demersal and bathypelagic

species found in the Deep Sea zone are only found at low density, although one notable exception is the Orange Roughy (*Hoplostethus atlanticus*). This deep water species seems to be found worldwide with most populations discovered to date in the southern hemisphere. Its biology is poorly known but at the time of spawning (around July in Namibia) it forms dense aggregations around some topographical features with rocky bottoms (like seamounts).The species is naturally very long lived (>100 years), extremely slow growing (reaching maturity between 22 and 40 years) and is known to have low fecundity.

Tuna and tuna-like species, such as Albacore (or long-fin tuna; *Thunnus alalunga)* and big eye tuna (*Thunnus obesus*) are also found in the zone; these are thought to be highly migratory over the entire southern Atlantic. Other species present in the zone include broadbill swordfish (*Xiphias gladius*) and pelagic sharks such as blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*).

5.16.1.2 Human activity and population

Very important shipping lanes cross this zone off Namibia (routes between Europe and the Mediterranean Sea or North America, round the Cape towards the Indian Ocean and Persian Gulf and the Far East). However these shipping lanes are far enough offshore in an area where the winds and currents are predominantly for the South East so that any major accidental pollution incident occurring there has little chance of affecting the Benguela system proper. Like in the previous marine zones, extensive prospecting for hydrocarbon deposits has intensified in the last decade with extensive seismic surveys. To date no economically viable deposits have been detected.

5.16.1.3 Pressures and drivers of change

Table 68: Broad drivers of change and ecosystem-specific pressures in the Deep Sea ecosystem zone

Broad driver of change	Ecosystem-specific pressures
Habitat change	Incidental mortality of seabirds and turtles from long-lining
Exploitation	Exploitation and overexploitation of fish resources in this zone
Pollution	Seismic surveys for oil and gas
Invasive species	No relevant pressures identified in this zone
Climate change	Modification of currents
Illegal use	No relevant pressures identified in this zone

Table 68 relates the six broad categories of drivers of change to specific pressures within the Deep Sea ecosystem zone. As there is less human activity in this zone than the other marine ecosystems, there are fewer and generally less significant pressures.

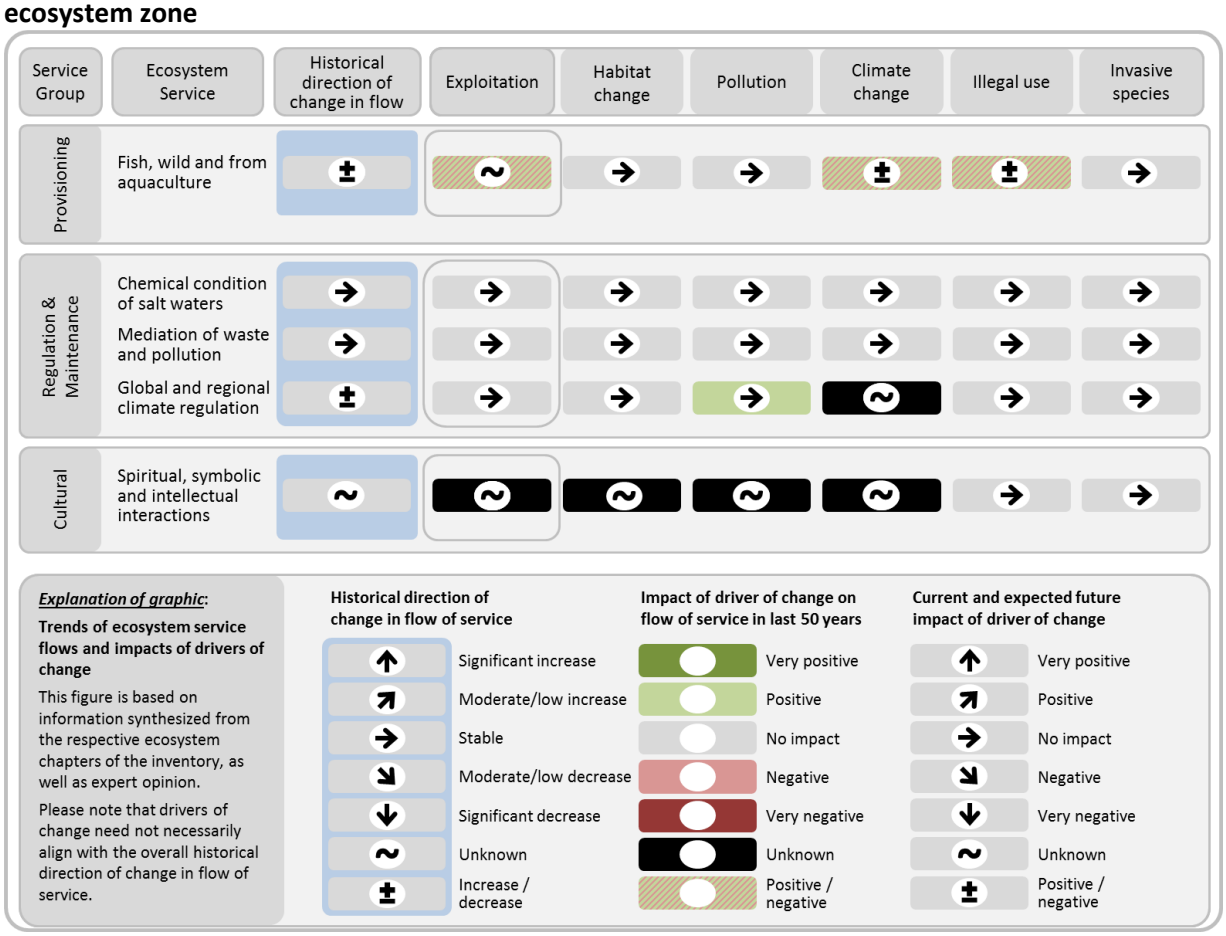
The Orange Roughy was overexploited due to over optimistic estimates of stock size at the beginning of the fishery, and the local stock collapsed within a few years after exploitation started. Exploitation of a number of other fish species also occurs in the zone.

Seismic surveys for oil and gas exploitation are thought to have contributed to pollution in the zone, while climate change may have some effects on the circulation of currents in the south Atlantic. Long-lining is contributing to the incidental mortality of endangered pelagic seabirds and turtles.

5.16.2 Inventory of main ecosystem services

This section presents an inventory of the main ecosystem services generated in the Deep Sea ecosystem zone. Figure 35 presents an overview of the trends in the flow of the broad classes of these services over the past 50 years, as well as the historical and expected future impact of the drivers of change on these services.

Figure 35: Overview of flows of services and impacts from drivers of change in the Deep Sea ecosystem zone



5.16.2.1 Provisioning

Table 69 details the specific services that relate to the broad provisioning ecosystem service classes relevant to the Deep Sea (and which are comparable to those classes specified in Figure 35). It also provides broad estimates of the scale of the population affected by the service, and the type of economic value associated with it.

Table 69: Overview of provisioning services in the Deep Sea ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Wild animals and their outputs	Orange roughy, tuna, broadbill swordfish, pelagic sharks and deep-sea red crab	International	Consumptive use

Description

Provisioning services result from fisheries for the production of food. Species caught include the tuna (mainly albacore and some big-eye), pelagic sharks (blue shark and shortfin mako), broadbill swordfish, deep-sea red crab and previously the orange roughy. These are primarily pelagic longline and pole and line fisheries. The deep-sea red crab fishery is discussed in the Shelf-Break and Slope zone.

The tuna fishery catches around 3,000 tons annually, but is commercially important. Catches of pelagic sharks have fluctuated between around 2,000 tons and 8,000 tons annually; in 2004, Namibia accounted for an estimated 3.3% of total world exports of shark products. Average catches of broadbill swordfish are approximately 660 tons per year.

Affected population

As these species are exported, the relevant population is international. Generally little processing of these species is done onshore, and so these fisheries have less of an impact on the coastal economies than those in the Continental Shelf and the Shelf-Break and Slope zones.

Change in flow over past 50 years

As a result of its characteristics and initially overly optimistic estimates of stock size at the start of the fishery in 1997, the orange roughy was heavily overexploited. An initial quota of 12,000 tons was given in 1997 (although 16,600 tons were caught), and the fishery declined quickly thereafter to less than 1,000 tons in 2001, 140 tons in 2007 and the fishery was closed in 2008.

There has been a marked drop in catches of tuna and tuna-like species in recent years. This is thought to be as a result of intense seismic survey activities for oil and gas in the zone, and that this disturbance may have altered the migration and aggregation pattern of these species.

Catches of pelagic sharks, broadbill swordfish and big-eye tuna are thought to have increased in recent years, but declared catches of sharks (blue shark and shortfin mako) in the fishery only account for about 60% of the total catch, and there are concerns about other species that are being caught (possibly illegally). This is also partially because the fishery not only operates in the Namibian EEZ, but also further offshore in the less regulated South East Atlantic Fisheries Organisation (SEAFO) area; however, as it catches species under the International Commission for the Conservation of Atlantic Tunas (ICCAT), it is unclear to whom these catches are reported.

Pressures and expected impacts on flow of service

Continued prospecting for hydrocarbon deposits could further alter the migration and aggregation patterns of tuna and tuna-like species, negatively impacting on the fishery, although the extent of this is not yet clear. It is also thought that climate change could also have similar impacts through altering the circulation of currents in the south Atlantic, but this is still uncertain.

It is not clear if the growth in the exploitation of pelagic shark species will continue. The potential for illegal fishing, due to the location of the fishery, is also a concern, but the extent of this is unknown as these are unreported catches. The orange roughy has significant potential as a fishery resource as

it is one of the most valuable species in the world, but its characteristics and present collapsed state make any recovery to exploitable levels a likely lengthy process.

5.16.2.2 Regulation and maintenance

Table 70 details the specific services that relate to the broad regulation and maintenance ecosystem service classes relevant to the Deep Sea.

Table 70: Overview of regulation and maintenance services in the Deep Sea ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Bio-remediation by micro-organisms, algae, plants, and animals	Waste water cleaning/degrading oil spills	Regional	Indirect use
Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	Absorption of pollutants	Regional	Indirect use
Filtration/sequestration/storage/accumulation by ecosystems	Absorption of pollutants	Regional	Indirect use
Dilution by atmosphere, freshwater and marine ecosystems	Dilution of pollutants	Regional	Indirect use
Chemical condition of salt waters	Maintenance of condition	Regional	Indirect use
Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	Global	Indirect use
Micro and regional climate regulation	Climate regulation	Regional	Indirect use

Description

The mediation of waste, toxins and other nuisances happens both at the level of the biota, which assist with waste water cleaning and degrading oil spills as well as absorbing pollutants, and at the level of the ecosystem which also works to absorb and dilute pollutants. The maintenance of physical chemical and biological conditions relates to climate regulation at both a global level, through carbon sequestration, as well as at micro and regional levels.

Affected population

The services relating to the mediation of waste, toxins and other nuisances are primarily relevant at a regional level, as they also impact on neighbouring ecosystem zones; the same goes for micro and regional climate regulation. There is likely to be minimal direct impact on human populations from these services, however. Carbon sequestration is important to the global population to the extent that it affects global climate change.

Change in flow over past 50 years

There is not thought to have been much change in the flow of services relating to the mediation of waste, toxins and other nuisances as there are limited pressures resulting from pollution in the zone. Similarly, the maintenance of the condition of sea water in the Deep Sea zone is not thought to have

changed substantially. Carbon sequestration is estimated to have increased as a result of increased global carbon emissions, while any changes in micro and regional climate regulation are not well understood.

Pressures and expected impacts on flow of service

No significant pressures surrounding pollution are anticipated, so limited change in the flow of these services is expected. Carbon sequestration is likely to continue increasing as carbon emissions increase; however the capacity of the ecosystem zone to continue providing the service, and the effects of climate change, are unclear.

5.16.2.3 Cultural

Table 71 details the specific services that relate to the broad cultural ecosystem service classes relevant to the Deep Sea.

Table 71: Overview of cultural services in the Deep Sea ecosystem zone

Ecosystem Service Class	Specific Service	Relevant Population	Type of Economic Value
Scientific	Research	International	Non-consumptive use
Educational	Education on marine environment	National	Non-consumptive use
Existence	Relating to marine environment and species	International	Existence
Bequest	Relating to marine environment and species	International	Bequest

Description

Cultural services relating to the Deep Sea zone are primarily based around scientific research, marine education and existence and bequest services derived from the marine environment and the species within them. There are few, if any, recreational activities that take place within the zone.

Affected population

The research, existence and bequest services are relevant to international populations due to the importance of the species within the ecosystem zone. Education around the marine environment is important nationally.

Change in flow over past 50 years

Research and education services are thought to have increased over the past 50 years as a result of increased human activity and interest in these areas, and particularly following independence. Existence and bequest services, and what affects them, are generally not well understood.

Pressures and expected impacts on flow of service

It is generally unclear what impacts the different pressures will have on the flow of these cultural services.

5.16.2.4 Interactions between ecosystem services

The long line pelagic fishery targeting sharks is resulting in some mortality of endangered seabirds, although this is thought to be happening to a lesser extent than in the Shelf-Break and Slope zone. There are also risks to endangered turtles from these activities.

5.16.3 Criteria for prioritisation of ecosystem services

5.16.3.1 Current and future expected impacts on the flow of the service

The tuna fishery is thought to be under pressure from seismic surveys and climate change, while there may be threats to pelagic sharks from undeclared catches.

5.16.3.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

There are no relevant threats from unsustainable water uses in this ecosystem zone.

Expansion of urban areas and increasing industrialisation

There are no relevant threats from unsustainable water uses in this ecosystem zone.

Threats and impacts of climate change

Climate change could impact on the tuna fishery by altering the circulation of currents in the south Atlantic.

Rapid expansion of mining and prospecting

There are no relevant threats from mining in this ecosystem zone, but oil and gas exploration may be putting pressure on the tuna fishery.

Unsustainable land management practices

There are no relevant threats in this ecosystem zone.

Uncontrolled bush fires

There are no relevant threats in this ecosystem zone.

Alien invasive species

There are no relevant threats in this ecosystem zone.

Illegal harvesting and trade of wildlife and forest and plant resources

There may be undeclared catches of pelagic sharks putting pressure on this fishery.

Human-wildlife conflict

Fishing in the zone is contributing to the mortality of endangered seabirds and turtles.

5.16.3.3 Economic importance (current and potential)

The orange roughy has the potential to be of economic importance, but was severely overfished and would take a significant amount of time to be restored to fishable levels. The tuna and pelagic shark fisheries are also economically important.

5.16.3.4 Affected population (size and socio-economic characteristics)

There is limited onshore processing of fish catches from this zone; the tuna and pelagic shark fisheries probably have the greatest impact as a result of revenue raised through them.

5.16.3.5 Availability of data and valuation methods

Data estimates should be available for stocks of fish resources in this zone. Research conducted by the Ministry of Fisheries and Marine Resources (MFMR), the Benguela Current Commission and institutes such as SANUMARC are important sources of data.

5.16.4 References

Benguela Current Commission. 2011. Annual State of Fish Stocks Reports. Benguela Current Large Marine Ecosystem, 2nd Edition, 91 pp. BCC, Windhoek, Namibia.

Boyer D.C., Hampton I. 2001. An overview of the living marine resources of Namibia. S. Afr. J. mar. Sci. 23: 5-35.

Boyer D.C., Kirchner C.H., McAllister M.K., Staby A., Staalesen B.I. 2001. The orange roughy fishery of Namibia: lessons to be learned about managing a developing fishery. S. Afr. J. mar. Sci. 23: 205-221.

Hampton I. 2003. Harvesting the sea (Chapter 5). Pp 31-69 in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Maartens L. 2003. Biodiversity (Chapter 7). Pp 103-133, in Molloy F, Reinikainen T (Eds) Namibia's Marine Environment. Directorate of Environmental Affairs, Ministry of Environment and Tourism. Windhoek, Namibia.

Roux J-P., Shannon L.J. 2004. Ecosystem approach to fisheries management in the Northern Benguela: The Namibian experience. Afr. J. mar. Sci. 26: 79-93

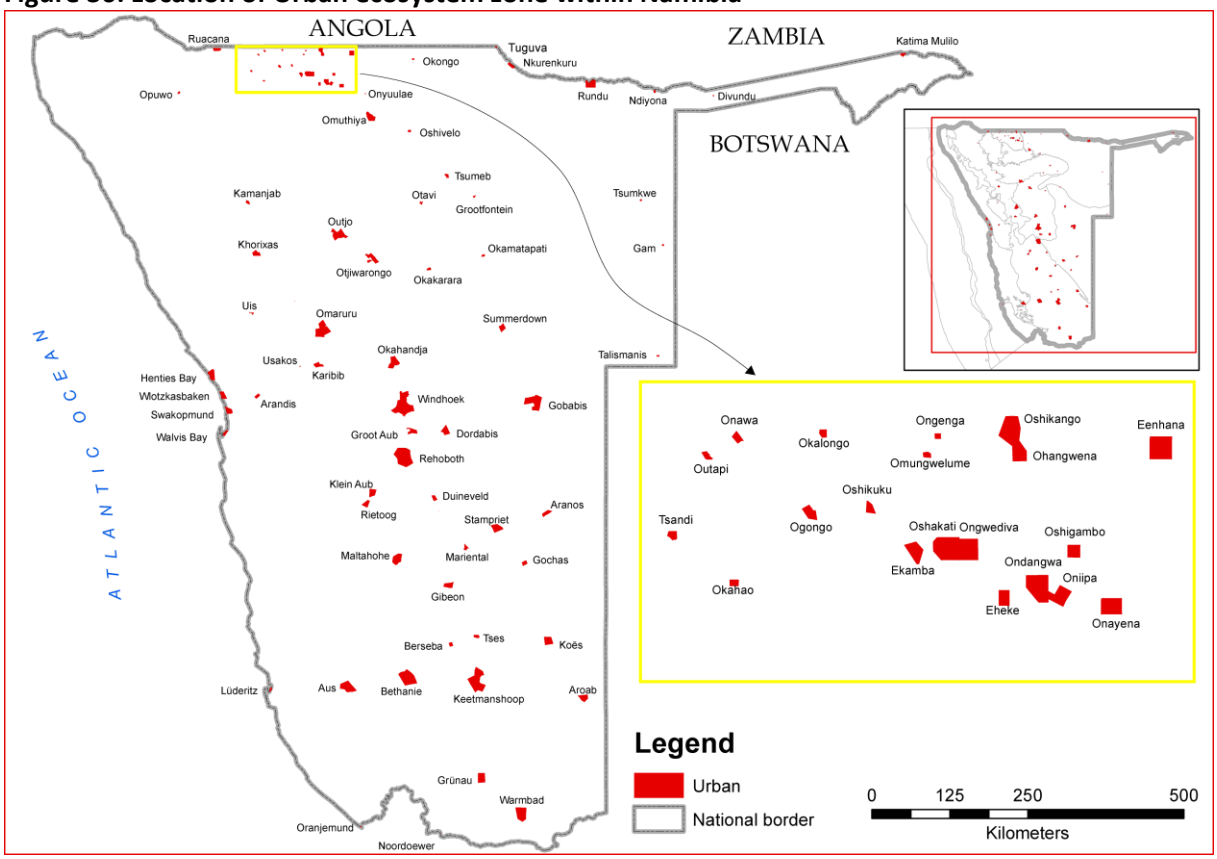
van der Lingen C.D., Shannon, L.J., Cury P., Kreiner A., Moloney C.L., Roux J-P., Vaz-Velho F. 2006. Resource and ecosystem variability, including regime shifts. Pp. 147-184 in: The Benguela: Predicting a Large Marine Ecosystem. Large Marine Ecosystem Series Vol.14., V. Shannon, G. Hempel, P. Manalotte-Rizzoli, C. Moloney and J. Woods Eds. Elsevier.

5.17 Urban

5.17.1 Description

Cumulatively, the Urban ecosystem zone comprises 85 distinct townlands and settlements which are identified as urban areas within Namibia, covering approximately 7,000 km^2 (0.85% of the area of Namibia) and home to an estimated 977,000 Namibians (46% of the population in 2011). Their locations within Namibia are shown in Figure 36. Each urban area is comparatively small and densely populated (the average population density across the Urban zone is 140 people per km^2, although some towns will be significantly higher than this). Urban residents obtain most of their food, water and energy for domestic and commercial use from elsewhere, and natural habitats in many of the urban areas have disappeared or been severely degraded.

Figure 36: Location of Urban ecosystem zone within Namibia



The focus on urban areas and their development has become increasingly evident in recent years; indeed the Ministry of Trade and Industry was renamed the Ministry of Industrialisation, Trade and SME Development, and a new Ministry for Urban and Rural Development was formed in 2015. Consequently there has been a growing focus on adding local value to primary products, and creating more diversified job opportunities. In the minds of many young Namibians, their future lies in towns and not rural areas where cash security is absent. Such changes in policy and ambition affect the delivery and use of ecosystem services in several ways.

Firstly, increasing numbers of people are attracted away from rural areas. Urban population growth rates in Namibia have been at around 4.5% per year since 1991, compared with rural growth rates of 1.5% over the same period (and in more recent years, populations in rural areas have been

declining); the total number of Namibians living in urban areas has increased by 33% since 2001. This migration has slowed the growth rate of the demand for natural resources in some rural areas.

Secondly, demands for certain ecosystem services are being concentrated in urban areas and are growing rapidly. The best example is the supply of water, where increasing volumes need to be transported over long distances from sources in rivers or aquifers to towns. Water reserves and supplies in other ecosystem zones have consequently declined, and are expected to decline further to keep pace with growing urban demand. For example, the direct and indirect consequences of pumping water from the Okavango River to supply consumers in the Cuvelai and central Namibia (including Windhoek) may have substantial impacts on the flow of the river.

Thirdly, rural economies and the use of ecosystem services are being changed by the substantial and growing flows of revenue coming from urban areas. Much of this is in the form of private remittances, and social grants and jobs being funded by tax income generated in towns. Trade and services are growing sectors in the local economies of many rural areas, opening new livelihood opportunities and diluting the focus on farming as the only viable use of land and occupation in these areas (although conversely increases in urban and private wealth are driving increases in the number of livestock being kept as capital in communal lands and some private farms). Woodlands are regenerating in some places where poles have been replaced by purchased bricks and wire as preferred materials to build and fence homes, respectively.

5.17.2 Ecosystem services

This report does not attempt to assess the ecosystem services derived from urban areas; urban areas primarily depend on surrounding or neighbouring ecosystem zones for the key goods and services (for example food and water). However it is worth noting that some regulation and maintenance services are likely to be particularly important in urban areas, for example the mediation of waste and pollutants, particularly gases, which are more concentrated in urban areas and can cause significant health problems.

Rural areas close to urban areas play an even greater role in the mediation of waste and pollutants, for example in the accumulation of toxic chemicals in groundwater, drainage lines and dams downstream of urban areas. Alien plants in urban areas may spread invasively into surrounding rural areas.

Furthermore cultural services relating to recreational areas, such as parks, in heavily urbanised zones are also likely to be of significant importance to local populations; they can provide large benefits in terms of their impact on physical and mental well-being. Large urban populations can also increase the benefits derived from recreational activities in nearby ecosystem zones, as this increases potential demand for the services.

In general the ecosystem service framework also represents an opportunity to integrate environmental concerns into urban planning, and to help demonstrate the benefits that ecosystem services can deliver in an urban context. It is in the stages of urban growth and expansion that Namibia is currently experiencing in which ecosystem services can be most easily (and least expensively) incorporated into urban planning and development.

5.17.3 References

Bethune, S., Griffin, M. and Joubert, D. 2004. National Review of Invasive Alien Species – Namibia. Final Report to SABSP. Directorate of Environmental Affairs Discussion Document. Windhoek.

Billawer HW and MS Ekobo. 2002. A human geography atlas of Walvis Bay: Beyond the reintegration. Windhoek: Gamsberg Macmillan.

Khomas regional poverty profile : based on village-level participatory poverty assessment in Khomas Region, Namibia, December 2005-February 2006. Namibia, National Planning Commission

Mapani, B.S. and Schreiber, U. 2008. Management of city aquifers from anthropogenic activities: Example of the Windhoek aquifer, Namibia. Physics and Chemistry of the Earth, Parts A/B/C, 33(8–13): 674–686.

Mendelsohn JM, Jarvis AM, Roberts CS and Robertson T. 2002. Atlas of Namibia. David Philip, Cape Town. 200 pp.

Nickanor NNM. 2013 Food deserts and household food insecurity in the informal settlements of Windhoek, Namibia. Ph D Thesis University of Cape Town.

Pendleton W, Crush J and N Nickanor. 2014. Migrant Windhoek: Rural–Urban Migration and Food Security in Namibia. Urban Forum (2014) 25:191–205

RAISON. 2010. An atlas of Namibia's population: monitoring and understanding its characteristics. Ghost written for Central Bureau of Statistics, Namibia. 64 pp.

TRP Associates. 1996. 1995 Residents Survey Report. Prepared by TRP Associates for the Municipality of Windhoek, 30 May 1996.

Wamukonya. L. 1997. Study on energy consumption patterns of rural and peri-urban households in Namibia. University of California, Berkeley.

6 Synthesis of ecosystem services at the national level

This section provides an inventory of ecosystem services at the national level, based on a broad aggregation of the individual ecosystem zones in Section 3.2. This national-level assessment is split into services relevant to terrestrial ecosystem zones and those relevant to coastal and marine ecosystem zones. Following the overview of the national-level inventories, a national-level prioritisation of ecosystem services summarises the findings of the ecosystem-level prioritisation exercises.

6.1 Terrestrial ecosystem services

Figure 37 presents an inventory of ecosystem services relevant to terrestrial ecosystems at the national level. The flows of all provisioning services are estimated to have increased over the past 50 years, with those relating to livestock (primarily cattle farming and keeping, plants for material and energy use (particularly firewood) and surface water (for both drinking and non-drinking uses) perhaps increasing most significantly.

These have all been driven by increased exploitation, which has in turn resulted from increased human populations and per capita consumption of these services. Exploitation is expected to remain an upward pressure on the flows of almost all of these provisioning services, with the exception of perhaps the use of plants for nutrition, material and energy use, as other sources of food and energy and building materials become increasingly widely available.

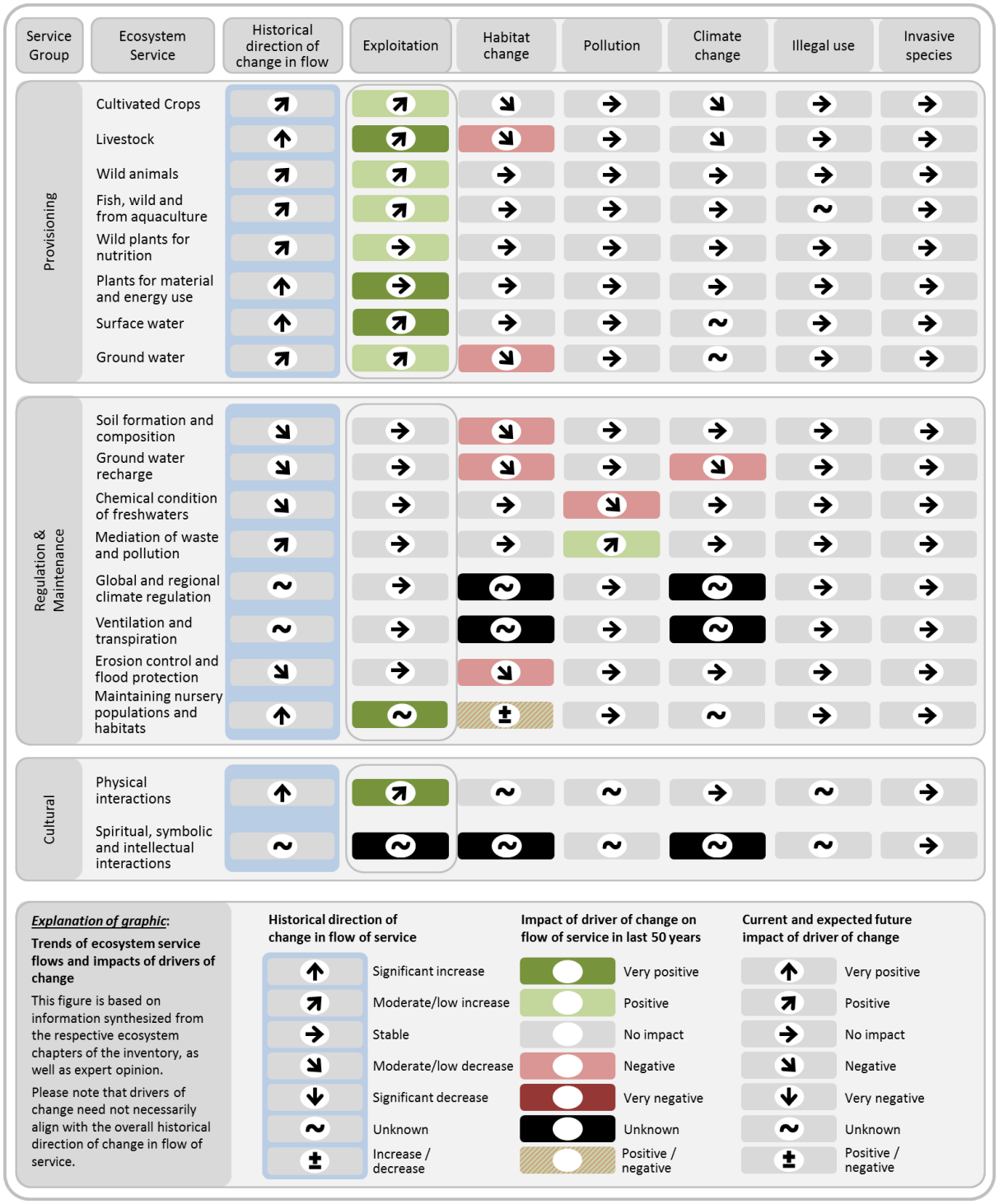
Habitat change represents a negative pressure on services related to livestock, particularly the farming of cattle, cultivated crops and groundwater. The pressure on livestock arises through overgrazing resulting in land degradation, as well as bush encroachment which limits the available land for cattle keeping and farming. Bush encroachment may be the principal pressure on groundwater services as it probably reduces recharge rates.

If climate change increases aridity, it is expected to have a negative impact on both cultivated crops and livestock via a reduction in the productivity of land used to deliver these services; however the extent of this negative impact is not well understood. The harvesting of fish, particularly in the North-East Rivers ecosystem zone, is a major pressure, although the extent of it in all rivers is not well understood.

In contrast to the flows of the provisioning services, the flows of most regulating services have either been trending downwards over the past 50 years, or are unknown. Soil formation and composition has been trending downwards as a result of habitat change through soil erosion and land degradation; it is indicated as declining on 9 of the 13 terrestrial ecosystem zone assessments. This has occurred for a variety of reasons, including overgrazing, bush encroachment and loss of woodland. Negative pressures are expected to continue, which could in turn impact on the ability of ecosystem zones to deliver provisioning services relating to livestock and crops.

Groundwater recharge is also estimated to have reduced over the past 50 years (indicated as such in 7 of the 13 terrestrial ecosystem zone assessments); this is primarily as a result of bush encroachment (habitat change), and is expected to continue. Climate change may have had a negative effect on groundwater recharge if higher carbon dioxide levels have increased the rate of bush encroachment.

Figure 37: Flows of ecosystem services and impacts from drivers of change in terrestrial ecosystem zones



In ecosystem zones with perennial rivers, the chemical condition of these freshwaters is an important service. The condition of the Orange River in the Nama Karoo has declined as a result of pollution from industry and agriculture in South Africa and this is expected to continue. Erosion control and flood protection may have also declined, particularly in the Cuvelai Drainage ecosystem zone, as a result of soil erosion and deforestation.

The two classes of services that are thought to have increased over the past 50 years are the mediation of waste and pollutants and maintaining nursery populations and habitats. The former relates largely to waste and pollutants in freshwater systems, which is thought to have increased because of increased pollution (albeit from relatively low levels) resulting in the ecosystem zones delivering greater services in this regard (and the level of pollution not yet being significant enough to impact on the ecosystem zone's ability to deliver the service). Pollution is expected to continue, but at relatively low levels.

Pollution from towns in the Urban ecosystem zone may have substantial downstream impacts on groundwater and surface water in drainage lines and dams. The contamination of Swakoppoort Dam is the best example.

The maintenance of nursery populations and habitats has increased strongly over the past 50 years, thus supporting the significant recovery of wildlife numbers in Namibia. This has been primarily as a result of the increased use and better management of land for conservation purposes to meet rising demands for wildlife products in the form of meat, trophies and tourism. The ongoing impact of the exploitation driver is not clear as it is unlikely that additional areas will be designated as conservation areas, but better management could further contribute positively to this service. The effect of climate change is not clear as it may impact different conservation areas in different ways.

The services relating to global and regional climate regulation and ventilation and transpiration are generally not well understood in terms of their flows, as the impacts of drivers of change such as habitat change (i.e. deforestation and bush encroachment) and climate change on the services are still being investigated.

Cultural services relating to physical interactions have increased significantly over the past 50 years, primarily as a result of increased recreation, but there have also been increases in scientific, educational, entertainment and aesthetic services. These increases have largely been driven by increased exploitation of these services. The effects of habitat change, pollution and illegal use on these services are unclear; they all generally represent negative pressures but they are not necessarily significant enough to affect the delivery of the service. Illegal use (through poaching of species such as rhino and elephant) in particular could have significant negative impacts on recreational tourism if it continues to grow, but it is not having negative impacts at its current level.

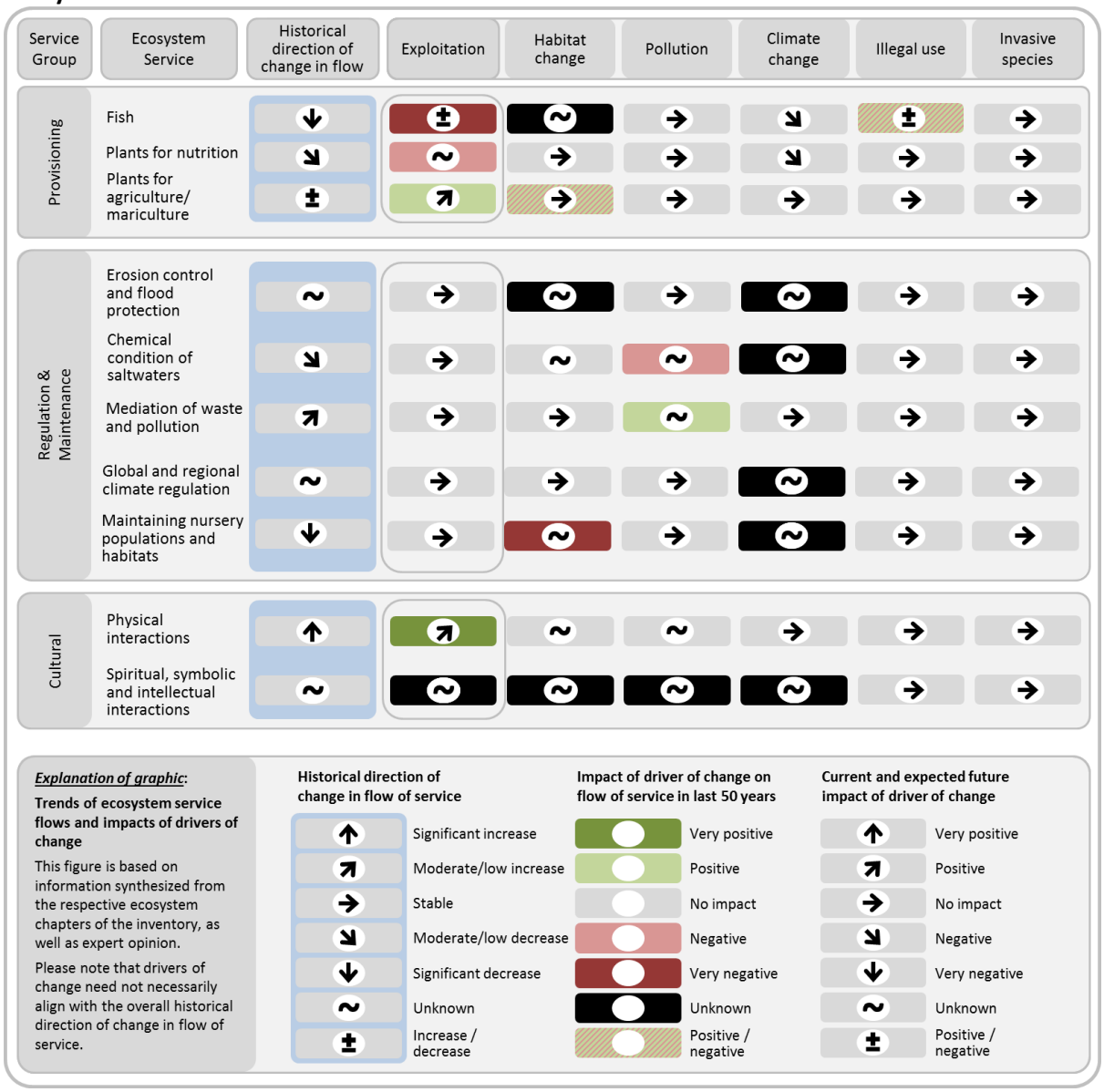
Services relating to spiritual, symbolic and intellectual interactions are generally not well understood, and the effects of the different pressures are not clear.

6.2 Coastal and marine ecosystem services

Figure 38 presents an inventory of ecosystem services relevant to coastal and marine ecosystem zones at the national level. The major provisioning service from these ecosystem zones is fish for food. Although different species of fish have seen their flows increase and decrease, the overall trend in the service over the past 50 years has been strongly negative, primarily as a result of the overexploitation of the small pelagic fish along the Continental Shelf and the knock on impacts on other fish species (such as hake). The effect of illegal use has been both positive and negative on different species (i.e. it has increased with regard to some species, such as rock lobster, but

decreased with respect to others following Namibian independence). There may have been impacts from habitat change, but these are not clear.

Figure 38: Flows of ecosystem services and impacts from drivers of change in coastal and marine ecosystem zones



There are expected to be mixed impacts from exploitation on different fish species going forwards. In some cases, exploitation is unlikely to have further negative impacts because the species have already been significantly overexploited (for example the small pelagic fish), but there may be increased exploitation of other species. The ongoing effects of illegal use are also expected to be mixed for different species, while the effects of habitat change are largely unclear.

Provisioning services from plants arise from the Coastal and Near-Shore zone. Wild plants for nutrition are represented by the collection of seaweed, but this has declined as a result of reductions in demand; it is not clear how this trend will continue (although the activity is currently not occurring on any commercial scale at present). Plants for agriculture and mariculture are guano

for fertiliser from seabirds, and kelp for abalone farming. The former decreased significantly as a result of the knock-on impacts of the overexploitation of the small pelagic fish stocks (representing habitat change), while the exploitation of kelp has increased to support the growth of mariculture activities, and this is expected to continue.

The flows of two of the regulation and maintenance ecosystem service classes have decreased over the past 50 years. The maintenance of nursery populations and habitats has decreased strongly, primarily with regard to the effects on juveniles of the hake stock from the overexploitation of the small pelagic fish stocks and other fishing practices (habitat change). The ongoing impacts of this are unclear, as are the effects of climate change. Coastal breeding habitats of seabirds have also been negatively impacted by habitat change.

The chemical condition of the sea water has also declined, largely as a result of pollution; this has also resulted in increasing flows of the mediation of waste and pollution services. The ongoing impacts of pollution are not clear as it is unknown if pollution levels will increase or decrease (likely increased human activity, but tighter and better enforced regulations and monitoring). Climate change may also impact on these services, but its extent is unclear.

The flows of the erosion control, flood protection, and global and regional climate regulation services are largely unclear. Erosion control and flood protection could be impacted by both habitat change at the coast (i.e. removal of natural barriers and defences) as well as climate change (through increasing sea levels) but the extent of these pressures is not known. The impact on global and regional climate regulation from these ecosystem zones, and the relevant effects of the pressures is also unclear.

As in the terrestrial ecosystem zones, recreational tourism, and consequently cultural services relating to physical interactions, has increased significantly over the past 50 years. This is as a result of increased exploitation, which is expected to continue growing. There have also been increases in scientific, educational, entertainment and aesthetic services, again as a result of increased exploitation. There may be ongoing impacts from pollution and habitat change, but it is unclear to what extent these pressures will impact on the delivery of the above cultural services.

Services relating to spiritual, symbolic and intellectual interactions with the Coastal and Marine ecosystem zones are generally not well understood, and the effects of the different pressures are not clear.

7 Roadmap for the prioritisation of ecosystem services at the national level

This section summarises the findings of the ecosystem-level prioritisation exercises, highlighting those services that either appear multiple times within a criterion or are of particular relevance to it. Where appropriate, distinctions are made between different ecosystem zones or broader areas within Namibia.

7.1 Current and future expected impacts on the flow of the service

The provisioning services facing the most pressure on their current and future flows are **livestock farming** (particularly cattle) and **groundwater** (for a variety of uses). The former is related to **overgrazing** resulting in **land degradation** (and consequently the soil formation and composition services) and **bush encroachment**, consequently reducing the carrying capacity of the area for livestock farming. Bush encroachment is also reducing the rate of groundwater recharge, which may inhibit the provision of water from certain aquifers.

In the riverine ecosystem zones (NE Rivers and the Orange River of the Nama Karoo and the Succulent Karoo), the **condition of the freshwater and the mediation of waste and toxins** are under pressure from **pollution and abstraction of the water** reducing in its flow (in the Orange River this is primarily from upstream uses in South Africa). In the NE Rivers **fishing** is under pressure as a result of potential **overexploitation**, as well as some threats from pollution.

The main pressure in the Coastal and Marine ecosystem zones relates to **pollution**, which is threatening the condition of the water, and consequently the **habitat** of many commercially fished and ecologically **important species**. The long term effects of potential changes in the Benguela upwelling system are not well understood, but could be significant on the wider ecosystem. In some instances the **overexploitation of fish stocks** has already occurred, and limited changes in their flows are expected without significant intervention.

7.2 Services affected by critical threats identified in NBSAP2

Unsustainable water uses

Increased abstraction of water from the Okavango River could reduce flows and further affect the delivery of a number of regulation and maintenance services (relating to the mediation of waste and pollutants, the maintenance of the condition of freshwaters and the transport and storage of sediments). Overexploitation of some (particularly fossil) aquifers has also occurred; for example the Koichab aquifer in the Namib Sand Sea which is used to supply water to Lüderitz. Increased abstraction from and pollution of the Orange River upstream in South Africa represents a limited threat to downstream uses and related ecosystem functions in Namibia.

There are threats from **unsustainable water use by mining**. Although desalination facilities have been established, with more planned, they have not taken over (as intended) as the main supply of water for mines.

The growth in demand for **surface water from dams**, primarily from urban areas such as Windhoek, is unsustainable. Alternative water supply sources, such as from the NE Rivers or groundwater from the Karstveld, are therefore being explored as possibilities to meet this growing demand. The

provisioning of surface water also faces pressure from increased pollution, particularly through industrial effluent and human waste from the growth in informal settlements.

Additionally, **climate change** could potentially result in greater variability in annual rainfall and lower average annual rainfall, reducing the recharge rates of the dams and increasing the likelihood that abstraction will become unsustainable.

Expansion of urban areas and increasing industrialisation

Industrialisation is mainly thought to represent pressures in the riverine (NE Rivers), central, and coastal ecosystem zones as a result of pollution. Increased pollution in the NE Rivers, particularly the Okavango, would negatively affect the chemical condition of the water, as well as threatening fish populations, particularly if it affects Lake Liambezi. Industry at the coast discharges effluents into Namibian waters, and if this grows as a result of **processing materials from seabed mining** (e.g. phosphate), it could increase pollution significantly, affecting the seawater quality along the shelf and consequently marine productivity there.

Windhoek's population is growing rapidly as is its industrial footprint, particularly in the northern industrial area and the Brakwater area just north of Windhoek, which is evolving from a series of smallholdings to a more industrial area. Industrialisation is increasing water usage in towns, which is in turn increasing pressure on water supplies. Urban areas are not necessarily a threat to ecosystem services; increased rural to urban migration is reducing pressures on natural resources in many rural areas, such as wood for the construction of houses and the hunting of small mammals and birds for food. However the **incorporation of ecosystem services and their benefits into urban planning** could help to ensure that environmental concerns are taken into consideration and any potential issues limited, during the growth of urban areas.

Threats and impacts of climate change

The increased aridity that could result from climate change is likely to further reduce areas where livestock and crop **farming** is economically viable, as well as potentially affecting groundwater recharge and the provision of groundwater (by encouraging bush thickening). In marine ecosystems, climate change may impact on the Benguela upwelling system, which could in turn affect primary productivity and the retention and survival of fish eggs and larvae; however these possible impacts are not yet well understood.

Rapid expansion of mining and prospecting

Mining is a occurring in the north and south western areas of Namibia and is planned along and over the Continental Shelf on the seabed off the Namibian coast. Terrestrial mining had until recently generally been fairly isolated from human activities, and consequently represented a limited pressure on ecosystem services, but it is increasingly encroaching on human populations (for example in Kunene and Tsumeb). Its rapid expansion could impact on tourism services and local biodiversity if not properly managed, as well as presenting the threat of local pollution.

Seabed mining for phosphate could represent a threat to the benthic habitat and the fish species and their juveniles along and over the shelf; it could also have negative impacts on water quality. This mining is still in planning stages, however.

Unsustainable land management practices

The major threat from unsustainable land management practices relates to overgrazing, particularly in northern and central areas. This is leading to land degradation and potentially bush encroachment, and is lowering the carrying capacity of these areas for livestock, as well as negatively impacting on the provision of some INPs such as Devil's Claw. Bush encroachment may be in turn reducing the rate of groundwater recharge. The extent of this overgrazing varies between and within ecosystem zones.

Uncontrolled bush fires

Uncontrolled bush fires are most prevalent in the Northern Kalahari Woodlands and less so in the Dry Kalahari Woodlands. The fires represent a threat to pastures and woodland, with the main resultant pressures on livestock farming and non-timber forest products (NTFPs). The greatest damage to burning has occurred in areas where there is little grazing by cattle, and consequently the impact of uncontrolled bush fires is greatest on NTFPs. Furthermore, areas that rarely burn have little grass, either because of intense grazing or because they are bush encroached; the thickening of bush in these areas is paradoxically a consequence of an absence or regular fires which would have otherwise controlled it.

Alien invasive species

There are thought to be only limited threats from alien invasive species in Namibia. *Prosopis* in riverbeds is reducing flows and possibly surface runoff into dams. The mariculture sector in the Coastal and Near-Shore zone introduces some potential threats from alien invasive species, but this is likely to be limited to the very local area and can be effectively mitigated.

Illegal harvesting and trade of wildlife and forest and plant resources

Poaching has become an increasing problem in the past few years, particularly with respect to black Rhino. An estimated 54 rhino were poached in Etosha in the first half of 2015, compared to 24 in the whole of Namibia in 2014, and zero incidents between 2006 and 2008; if left unchecked this could represent a threat to some cultural services, and Etosha and Kunene as key conservation habitats for these endangered species. The poaching of elephant in the north-east has also increased in recent years.

To the south of Namibia there have been increases in the illegal harvesting of succulent plants in the Succulent Karoo, and of !naras in the Namib Sand Sea; the latter could represent a pressure on some of the cultural services Topnaar people hold around the process of its harvesting.

Human-wildlife conflict

Human-wildlife conflict is most prevalent where there are predators and/or large mammals. Predators in the central region of Namibia among private farms are generally tolerated because of

the tourism value they bring, but in communal lands this is often less so (especially where community conservation initiatives such as conservancies are not in place). In these areas they represent a threat to livestock populations and sometimes human life. Large mammals such as elephant in the areas surrounding Etosha can cause damage to property, and additionally in the NE Rivers to crops.

7.3 Economic importance (current and potential)

Recreational tourism is of significant economic importance both at a national and a local level (particularly with regard to communal conservancies). The majority of tourists cite wildlife and landscapes as their reasons for visiting Namibia, and consequently biodiversity and the natural environment is critical to maintaining tourism revenues and the economic activities it supports. Recreational tourism is primarily based around both consumptive (i.e. recreational hunting) and non-consumptive (i.e. wildlife viewing) activities. There is still significant scope for growth in some areas, for example in the north-east, as well as in State Protected Areas such as the Skeleton Coast, Khaudum and Tsau //Khaeb which are in the process of being developed for these activities.

Where livestock and crops are farmed commercially, they are also of economic importance locally and nationally. The provision of water, particularly surface water from dams in the Highland Acacia Savanna and aquifers to urban areas, is also important in that it supports many other economic activities.

The fisheries sector has significant economic potential. The overexploitation and collapse of the small pelagic stocks over the shelf has resulted in significant job losses in coastal towns such as Walvis Bay and Lüderitz, as well as losses in national export earnings. The collapse of these stocks has also had further negative impacts on the economically important hake fishery, as well as guano production and biodiversity (supporting tourism) at the coast.

7.4 Affected population (size and socio-economic characteristics)

At a national scale, tourism is important not only for the jobs it provides, but also to many Namibians who value recreational tourism, particularly at the coast, themselves. The provision of water is also a service that is important nationally. Some cultural services, such as those relating to certain ways of life, or particular areas representing ‘home’, are also likely to be important to significant proportions of the Namibian population.

For socio-economic reasons, it may be appropriate to prioritise ecosystem services relating to the provision of food, as its production in rural areas is frequently for own-use. Furthermore, this may motivate prioritising certain service in the NE Rivers and the Northern Kalahari Woodlands: these ecosystem zones encompass the Kavango East and West and Zambezi regions and which have the highest incidences of poverty in Namibia. Groups such as the San are often amongst the poorest in society, and so prioritising services that are particularly relevant to them, such as certain cultural services, may also be motivated by this criterion.

7.5 Availability of data

Those services with the greatest availability of data are traded provisioning services (such as livestock, crops and fish). It may also be possible to estimate the number of tourists in different ecosystem zones.

8 Conclusions

This report presents an overview of the main ecosystem services in Namibia. Ecosystem services are disaggregated at the level of 13 terrestrial and 4 coastal/marine ecosystem zones which allow an assessment of how the types of ecosystem services vary across the country, how their flows have changed in recent decades and what pressures they are currently facing.

As a result of increasing human populations and the opening up of the country post-independence, the exploitation of many services has increased quite significantly in recent decades Namibia. Key examples of these are provisioning services such as livestock farming and keeping, the production of crops and the provision of water for a variety of uses.

However many ecosystem services are facing increased pressures on their flows. While livestock farming and keeping has increased, particularly in communal areas, this has led to overgrazing and consequently land degradation in many areas; this may be represented by declines in associated regulation and maintenance services, such as those related to soil formation and composition. As a result of this, the carrying capacity of these areas has been decreased, and consequently their future ability to deliver the services related to livestock farming and keeping may be decreased.

The above example illustrates the interlinked nature of many ecosystem services: the exploitation of some may impact on the delivery of others (or on its own future delivery if it operates in a negative feedback loop). Furthermore, these linkages extend beyond the borders of a given ecosystem zone, and can affect the delivery of ecosystem services in neighbouring ecosystem zones, which in some cases may be in different countries.

Across many ecosystem zones, the same pressures are evident. Land degradation caused by overgrazing as described above is one, with bush encroachment another; the latter is thought to be reducing groundwater recharge rates. In riverine ecosystem zones, reduced flows, as a result of the abstraction of water, and pollution, from industrial discharge or agricultural return flows, is common, while in the marine ecosystem zones the overexploitation of fish stocks has been a relatively common occurrence.

It is also clear that there is a significant amount of uncertainty about the flows of certain ecosystem services and how various pressures will affect them going forwards. This is much more the case for regulation and maintenance and cultural services than it is for provisioning; it is much easier to understand the effects of drivers of change on services of which uses and therefore flows can be directly observed.

For example, services relating to spiritual, symbolic and intellectual interactions are generally not well understood, and the effects of the different pressures are not clear. Global and regional climate regulation services also require further investigation, particularly as changes in their flows have the potential to wreak severe and wide-ranging impacts across Namibia, and indeed the world. In general, there is a clear and pressing need for greater research into many regulation and maintenance and cultural services.

Recognising that many services are under pressure (or have already seen declines in their flows), there is a need to ensure that ecosystem services are incorporated into decision making; this report

suggests 5 criteria for prioritising ecosystem services for this purpose. This prioritisation ultimately needs to be decided by stakeholders.

One way of incorporating ecosystem services into policy and decision making is to undertake economic valuations of these services. For example, including the value of ecosystem services and their benefits into urban planning could help to ensure that environmental concerns are taken into consideration and any potential issues limited during the growth of urban areas. Where possible, economic valuations can attribute monetary values to services, while emphasising their linkages with other ecosystem services, especially those for which it is often not possible or appropriate to attribute a monetary value. This is discussed in greater detail in the accompanying *Roadmap for the economic valuation of ecosystem services in Namibia* (page 244).

9 General references

De Groot, R., Fisher, B. and M. Christie (2010). Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. TEEB.

Haines-Young, R. and M. Potschin (2010). The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D.G and C.L.J. Frid (eds.): Ecosystem Ecology: A New Synthesis. Cambridge University Press, British Ecological Society, pp. 110-139.

Haines-Young, R. and M. Potschin (2013). Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August – December 2012. Report to the EEA.

Landers, D. and A. Nahlik (2013). Final Ecosystem Goods and Services Classification System (FEGS-CS). U.S. Environmental Protection Agency, Washington, DC.

Mace, G.M. and I. Bateman (2011). UK NEA Chapter2: Conceptual Framework and Methodology. Available here: http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx [Accessed September 2015].

Mendelsohn, J., Jarvis, A., Roberts, C. and T. Robertson (2009). Atlas of Namibia. A portrait of the land and its people. Sunbird Publishers, Cape Town, South Africa.

MET (2012). Statistical Report on 2011 Tourist Arrivals. Ministry of Environment and Tourism, Government of the Republic of Namibia, Windhoek, Namibia.

MET (2013). Report on the Namibia Tourist Exit Survey 2012 – 2013. Ministry of Environment and Tourism, Government of the Republic of Namibia, Windhoek, Namibia.

MET (2015). Namibia's Second National Biodiversity Strategy and Action Plan 20133 – 2022. Ministry of Environment and Tourism, Government of the Republic of Namibia, Windhoek, Namibia.

MET (2015a). Tourist Statistical Report 2014. Ministry of Environment and Tourism, Government of the Republic of Namibia, Windhoek, Namibia.

Millennium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

NSA (2012). Namibia Household Income and Expenditure Survey (NHIES) 2009/2010. Windhoek, Namibia.

Potschin, M. and R. Haines-Young (2011). Ecosystem services: exploring a geographical perspective Progress in Physical Geography. 35(5), 575-594.

TEEB (2010). The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan, London and Washington.

UN (2012) System of Environmental-Econoici Accounting 2012: Central Framework. United Nations, New York.

UN (2014). System of Environmental Economic Accounting 2012: Experimental Ecosystem Accounting. United Nations, New York.

Winn, J. and M. Tierney (2011). The Drivers of Change in UK Ecosystems and Ecosystem Services. UK National Ecosystem Assessment, Chapter 3.

WTTC (2014). Travel and Tourism Economic Impact 2014 Namibia. World Travel and Tourism Council, London, United Kingdom.

Roadmap for the Economic Valuation of Ecosystem Services in Namibia

Final Report

Namibia Nature Foundation

2015

Table of Contents

1 Introduction

The *Development of an Inventory of Ecosystem Services in Namibia* report illustrates that the flows of a number of ecosystem services have either declined in recent decades or are threatened by increasing pressures. These ecosystem services lead to the provision of particular benefits, which in turn contribute to individual and societal well-being. Examples of these benefits include food, drinking water, equable climate, and recreation, and may also be spiritual or cultural in nature.

The economic valuation of ecosystem services is one approach that can assist with the mainstreaming of ecosystem services and their incorporation into decision-making. There has been an increased focus on economic valuation studies in recent years, particularly following the publication of The Economics of Ecosystems and Biodiversity (TEEB) report in 2010. The UK National Ecosystem Assessment (NEA) is one such example of a coordinated body of work that attempts to estimate the economic value of ecosystem services to promote their incorporation into policy making.

This report presents an overview of economic valuation concepts and suggests how the economic valuation of ecosystem services could be undertaken in Namibia. Such studies would effectively represent part of the *Main Study Phase* in implementing a TEEB Country Study (TEEB, 2013), which is consistent with what is presented in this report.

2 Economic valuation of ecosystem services

This section outlines the various concepts related to the economic valuation of ecosystem services. It starts by presenting the practical steps in conducting an economic valuation study and the Total Economic Value (TEV) framework as a typology for economic values, before providing an overview of the different approaches to economic valuation and the limitations in undertaking economic valuation studies. When considering all of this, it should be kept in mind that economic arguments for the conservation or continued delivery of ecosystem services are "in addition to, not in place of, ethical and scientific ones" (Fisher et al., 2008 p51).

2.1 What is economic valuation?

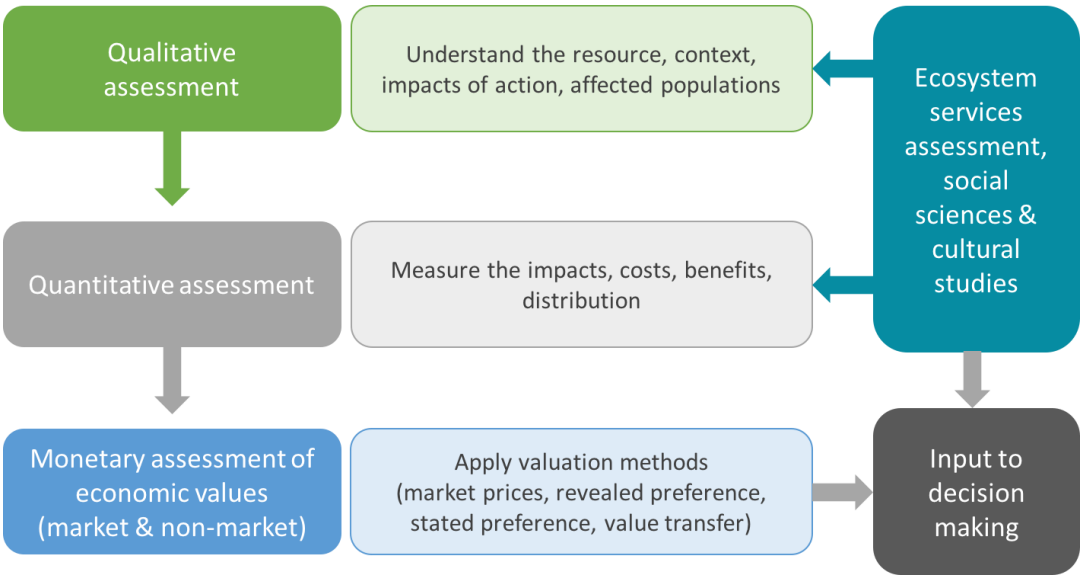
The economic valuation of ecosystem services relates to measuring the preferences that individuals hold for the benefits generated by these services. Valuation is expressed in monetary terms as this is a widely used *unit of account*; it enables the explicit consideration of ecosystem services in policy and decision-making where the costs and benefits of actions are generally sought in monetary terms. Expressed in its simplest terms, it is essentially asking individuals how much they are willing to pay for the ecosystem service.

The focus on preferences and the concept of willingness to pay is key to understanding the difference between economic values and exchange values. Exchange values are measured by the system of national accounts (SNA) and in practice correspond to market prices multiplied by quantities. Where ecosystem services and their benefits have market prices, their exchange values can significantly underestimate the economic values because they do not account for people who would be willing to pay more than the market price for the service. Furthermore, only a small subset of ecosystem services is associated with market prices.

In order to estimate economic values relating to ecosystem services it is therefore often necessary to undertake an economic valuation study. In practical terms, there are three steps, which are outlined below and illustrated in Figure 1:

1. **Qualitative assessment**: Understanding the ecosystem services provided and how these are expected to change under different scenarios. Economic valuation studies often compare the effects on ecosystem services and their benefits of a particular policy or intervention with a baseline 'business as usual' (BAU) scenario. This step should also broadly identify the likely population affected by the ecosystem services and their benefits under the different scenarios.
2. **Quantitative assessment**: Quantifying the change in the delivery of ecosystem services and the associated change in benefits to the affected population.
3. **Monetary assessment:** Estimating the economic value of the change in quantified ecosystem services / benefit impacts in monetary terms. This involves deciding what type of economic value evidence is required, and, based on the assessments in steps 1 and 2, what kind of evidence is feasible, and subsequently designing a strategy using appropriate economic valuation methods (see Section 2.3).

Figure 1: Economic Valuation is a Multidisciplinary Approach



Source: Eftec. Pers. Comm from Ece Ozdemiroglu.

There are two key implications from the above. The first is that economic valuation is a multidisciplinary approach, requiring input from economists and non-economists such as environmental scientists, ecologists, and the wider social-science community, especially in order to undertake the qualitative and quantitative assessment steps. The second implication is that economic valuation studies measure the value of a change, i.e. the economic value of the change in flow of particular ecosystem services and their associated benefits between different scenarios, and not the absolute value of the environment or of an individual resource.

Box 1: The Economic Value of Protected Areas in Namibia

A good example of an economic valuation study and the impacts it can have can be found in Namibia. A study commissioned by the UNDP/GEF project on Strengthening the Protected Areas Network in Namibia (SPAN) assessed the economic value of Namibia's protected area system (Turpie et al., 2005; Turpie et al., 2010) and consequently helped to motivate the Namibian Government to increase annual investments in the country's protected area network by more than 300% between 2006 and 2010.

This study can be used to put the three steps in undertaking an economic valuation study into context:

1. **Qualitative assessment**: The protected areas study compared a scenario that assesses the effects of increased investments in the protected area network to the BAU baseline scenario, primarily through the scope of ecosystem services related to biodiversity and recreational tourism. Affected populations included foreign and domestic tourists, and local Namibian populations around the protected areas which would receive increased investments.
2. **Quantitative assessment**: The investment scenario estimated that 77 additional lodges/camps would be developed after 20 years, accompanied by an increased number of tourist visits and therefore tourism expenditure.
3. **Monetary assessment:** Market valuation methods were used to estimate the economic value of the projected increase in tourism, and compare this to the costs of investment.

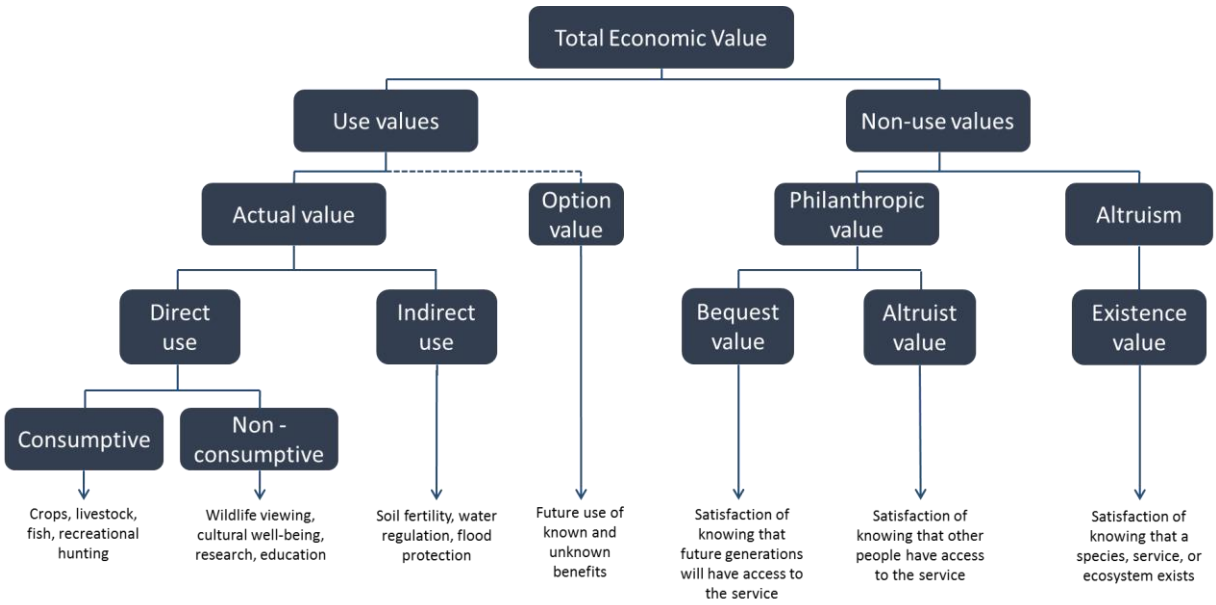
2.2 A typology of economic values: the TEV framework

Economic values can be thought of as a set of component parts; this is illustrated by the total economic value (TEV) framework presented in Figure 2. The different types of economic value illustrate the different ways in which humans interact with the environment. The main distinction is between use and non-use values; use values involve a physical interaction with the ecosystem service, while non-use values do not. A brief description of each component of TEV is provided in Table 1.

In general, only direct use values have market prices attached to them, and even then these prices can differ greatly from economic values. One example would be that although there is a price for entry and accommodation in Etosha National Park, which represents the price that people pay for wildlife viewing activities, there are likely to be many individuals who would be willing to pay significantly more (for example, entry to Etosha is N$80 per foreign adult per day, compared to R264 for Kruger National Park in South Africa).

Non-use values can be particularly hard to estimate, as these frequently relate to cultural services and moral, religious or aesthetic properties that are almost never associated with monetary exchanges. The following section outlines economic valuation methods that can be used to attempt to overcome some of these difficulties.

Figure 2: Total Economic Value Framework



Source: Adapted from Pascual et al. (2010)

Table 1: Typology of economic values in the TEV framework

Value type	Value sub-type	Description
Use values	Direct use value	Results from direct human use of the ecosystem service. This may be consumptive (e.g. consumption of food or raw materials; trophy hunting) or non-consumptive (e.g. aesthetic benefits of wildlife or landscape viewing). Direct use values primarily relate to provisioning services, although they do incorporate some cultural services as well. There are often monetary prices associated with ecosystem services that have direct use values.
	Indirect use value	Generally derived from the regulation services provided by biota and ecosystems (e.g. air quality; carbon sequestration; flood prevention). Such services are generally not reflected in market transactions, and therefore not associated with monetary prices. Other examples of services associated with indirect use values include the use of landscapes and wildlife in film and photography, and scientific research. These services may be reflected to some extent in the market place, for example through filming licences, or revenue from related products.
	Option value	Relates to the future use of a given ecosystem service for personal benefit. Option values can be held with regards to provisioning, regulating and cultural services. One example of an option value would be an individual valuing the potential to go on a wildlife-viewing holiday in the future. Option values are generally not associated with monetary prices.
Non-use values	Bequest value	Value attached by individuals to the fact that future generations will also have access to the benefits from species and ecosystems (inter-generational equity concerns). Bequest values are only associated with a subset of cultural values that are generally not reflected in market transactions, and therefore not associated with monetary prices.
	Altruist value	Value attached by individuals to the fact that other people of the present generation have access to the benefits provided by species and ecosystems (intra-generational equity concerns). Altruistic values are only associated with a subset of cultural values that are generally not reflected in market transactions, and therefore not associated with monetary prices.
	Existence value	Value related to the satisfaction that individuals derive from the mere knowledge that species and ecosystems continue to exist. Existence values are only associated with a subset of cultural values that are generally not reflected in market transactions, and therefore not associated with monetary prices.

Source: Adapted from Pascual et al. p14.

2.3 Approaches to economic valuation

2.3.1 An overview of different economic valuation methods

Primary economic valuation "involves estimating the value of ecosystem services through the collection of data that are specific to the ecosystem(s), service(s) and beneficiaries that are under consideration". There are three approaches to primary valuation, and the applicability of each of these approaches depends on the type of data that is available and the types of services or economic values that are to be assessed.

The starting point for primary valuation studies is the use of market transaction data (such as prices, costs and quantities) relating directly to the ecosystem service under consideration; approaches using these data are known as ***direct market valuation approaches***. The main advantage of these approaches is that they reflect actual choices that individuals make, and therefore their preferences or the costs that they face.

Market-price methods are most commonly used to estimate the value of provisioning services, of which the resulting commodities are often traded (such as meat and timber). Prices from well-functioning markets can represent a reasonable approximation of economic value (Brouwer et al., 2013; p.62), and such data is relatively easy to access and compile.

In cases where markets are not particularly well functioning, it can be possible to use **shadow prices** instead. These adjust for transfer payments, market imperfections and policy distortions, to better reflect the true economic value of ecosystem services. Estimating shadow prices can be complex in some cases and very simple in others; for example it may just be a case of identifying existing taxes (such as VAT) and removing them from market prices.

Production methods are another type of direct market valuation approach. They estimate the extent to which a given ecosystem service contributes to another ecosystem service that is traded on an existing market (i.e. its role in the production function of this traded service). Production methods can be used to estimate the impact of pressures such as deforestation and water pollution on productive activities such as fishing, hunting, and farming. However the production functions of ecosystem services are rarely well understood, which can make these methods unreliable.

Cost-based methods assess the costs that would be incurred to maintain a given level of benefits in the face of particular pressures. Examples include replacement costs (artificial substitutes for ecosystem services) and restoration costs (costs of restoring degraded ecosystems or ecosystem services). These methods have the disadvantage of not having any link to individual preferences or the benefits provided by the ecosystem/ecosystem service of interest.

The major barrier to using direct market valuation approaches is that market transaction data relating directly to ecosystem services is only available for a small subset of these services. Where these data are not available, it may be possible to derive market information from parallel markets that are indirectly associated with the ecosystem service to be valued. These are known as ***revealed preference (RP) approaches***, where individuals reveal their preferences for given ecosystem services through their choices in associated markets. Three types of RP approaches are outlined below.

The **travel cost method** is based on the premise that time and travel cost expenses incurred by individuals to benefit from an ecosystem service can represent a proxy for the 'price' of that ecosystem service. The most common application of the travel cost method is to estimate the economic value of visits to recreational sites, as travel expenses (e.g. time and fuel) need to be incurred to enjoy recreation. Another example could be valuing the time taken to collect natural resources such as water and fuelwood.

In the context of recreation, travel cost methods tend to refer to explaining the demand for a given recreational site (i.e. why people choose to go there). However they are not very good at estimating how this demand (both the number and type of visitors) will change if the characteristics of the site change (for example due to investments in conservation). **Random utility models** can explain how visitors will choose between different sites with different characteristics (for example the presence of different species of wildlife and the likelihood of seeing them), and therefore can be used to estimate the difference in economic value attributed to these different characteristics.

Hedonic pricing is another RP method, in which ecosystems and their services are seen as characteristics of a market good. The most commonly seen example of this is the valuation of environmental amenities (for example landscapes) through differences in prices observed in the housing market.

RP methods are appealing because they rely on actual or observed market data. However they are generally very data intensive and require complex analysis to estimate values (for example the hedonic pricing of environmental amenities with regards to the housing market would require spatially disaggregated panel data on property sales and characteristics alongside other information such as socio-economic data). Furthermore, they cannot estimate non-use values.

The only set of economic valuation methods that can estimate non-use values (as well as use values) are ***stated preference (SP) approaches***. These methods simulate a demand for ecosystem services, most commonly through specially designed surveys. There are two main types of SP approaches: **contingent valuation (CV)**, which asks respondents either for their maximum willingness to pay for an improvement in a service or whether they would accept a particular service improvement at a given cost; and **choice modelling (CM)**, which constructs a trade-off between ecosystem services and other goods and a monetary value.

The two methods consequently differ in the situations in which they are most appropriately applied. CV treats a good or service as a bundle of its characteristics, and values them together, while CM presents the individual attributes of the good and illustrates how they change under different policy options. As a result, CM can be a useful input to the design of policy or investment options, with CV used to test the preferred options.

Depending on the extent of the survey and the ecosystem services that are being valued, SP methods can be expensive and complex to design, and it can be a challenge to reflect individuals' true preferences in the results. However there are thousands of SP studies that have been undertaken and published (with many more unpublished due to commercial confidentiality), and they have shown that it is possible to generate informative and robust results with relatively small samples and straightforward study designs.

An alternative to primary economic valuation is ***value transfer*** which involves estimating the value of ecosystem services through the use of value data and information from other similar ecosystems and populations of beneficiaries. It effectively transfers the results of primary valuation studies undertaken for similar ecosystem services in different spatial or temporal settings to sites that are of current policy interest. However, the ecosystem services, beneficiaries and spatial and temporal settings must be *sufficiently* similar; this can be a significant challenge when there is not a strong body of varied existing primary valuation studies to rely on. Eftec (2009) provides a comprehensive guide to using value transfer.

2.3.2 Undertaking economic valuation studies

The appropriate economic valuation method will of course depend on the ecosystem service under consideration and the type of economic value that is being sought. However, there are broad suggestions that can be made regarding a hierarchy of approaches to undertaking economic valuation studies; these are presented below.

In general, market-price based direct valuation approaches are recommended as a starting point for economic valuation studies where possible. The advantage is that such data is generally easily accessible and it provides a link to individual preferences. If there are significant market distortions, the next best approach is to adjust these data using shadow prices.

However market price data are only available for a small subset of ecosystem services, and even then only capture direct use values. RP and SP studies can be used to provide more comprehensive economic value estimates. In order to capture all types of economic values, an SP study is necessary as it is the only approach that can capture non-use values. RP studies may be particularly useful in certain situations, such as the economic value of recreational sites and their characteristics (although it is worth noting that SP studies can also capture this data).

The use of production-based methods can be useful for estimating the monetary value of regulation and maintenance services which are linked to other services that are associated with market prices. The data requirements for production-based methods are quite significant, and they may not be feasible unless there is a strong understanding of the relationship between the ecosystem service and the market-priced good with which it is associated.

Cost-based methods are generally not recommended unless they directly address the policy option being considered (i.e. if it is about maintaining benefits in the face of increasing pressures on services). As they demonstrate the direct link to preferences or beneficiaries, there is a risk that monetary values generated by them could be misleading in terms of the economic value of the service of interest.

The design of an economic valuation study cannot only take into account the total cost or technical complexity of the methods involved; it must also look at value for money. For example, a study that focuses on market price data may be relatively cheap to implement because such data is likely to be easily accessible, but it can only be applied to a small subset of ecosystem services and can estimate only direct use values. A well-designed SP study may be more expensive and take longer to implement, but could estimate use and non-use values for a variety of ecosystem services and consequently provide more useful and comprehensive information to support decision making.

2.4 Limitations of economic valuation

In some cases it will not be possible to estimate economic values of ecosystem services at an acceptable level of validity. One suggested approach in such situations is the "adoption of ecological standards to ensure the sustainability of resources (such as the continued existence of species) which are not amenable to valuation"[43].

The major problem with regard to estimating robust economic values for ecosystem services is the lack of understanding of the science that relates ecosystems and their services, and consequently how these services contribute to the production of benefits that are ultimately valued by society (Bateman et al., 2011). How an ecosystem service will respond to a given change is firstly a scientific question, and this must be kept in mind when designing studies to estimate the economic value of a change.

In other cases the attribution of monetary values to ecosystem services may be considered inappropriate. This may be particularly the case with regard to certain cultural services which people are unwilling to trade off against money or other services (monetary values are the trade-off for market goods and services). In such a case it is necessary to incorporate these services alongside any monetary values when supporting policy or decision making.

[43] Bateman et al. (2011, p.192)

3 Suggested next steps

As outlined in Section 2, the economic valuation of ecosystem services should be undertaken with regard to well-defined policy options that affect the delivery of particular services. A starting point for considering policy options could be the prioritisation of ecosystem services provided in the *Development of an Inventory of Ecosystem Services in Namibia* report. As the delivery of many ecosystem services are interlinked with other services, each policy option could incorporate a number of ecosystem services. Five suggestions for potential issues or policy options to consider in economic valuation studies are presented in Sections 3.1 to 3.5 below. The exact nature of the economic valuation studies to be undertaken needs to be decided by MET.

A useful guidance document which could assist with the design of the economic valuation studies is the Targeted Scenario Analysis (TSA) framework (Aplizar and Bovarnick, 2013). It is consistent with the TEEB approach. The *Inventory* could also represent the basis for conducting a detailed Experimental Ecosystem Account using the methodology detailed by UN (2014).

3.1 Small pelagic fish stocks

The inventory indicated that small pelagic fish stocks have collapsed as a result of overfishing, and this is thought to be having adverse effects on a number of ecosystem services; one issue to consider would therefore be measures to rebuild these stocks. While the associated costs would be largely defined by the exact actions, the broad potential benefits can be thought of as follows:

- Increased small pelagic fish stocks resulting in increased consumptive use value (food);
- Increased productivity of the hake stock and consequently biomass and stock, resulting in increased consumptive use value (food);
- Increased biodiversity through the recovery of populations of regionally endemic seabirds (African Penguin, Cape Cormorant, Cape Gannet) and cetaceans (dusky dolphin, southern right whale dolphin). This could impact on use (recreational tourism; guano production for fertiliser) as well as non-use values;
- Environmental benefits from the restoration of the Northern Benguela ecosystem (i.e. indirect use values from regulation and maintenance services);
- Wider socio-economic benefits as a result of increased employment, exports etc.

Such a study would consequently require some modelling of the relationship between the small pelagic stocks and the populations and biomass of other species, such as hake and particular seabirds.

3.2 Bush encroachment

Bush encroachment is a significant pressure across much of Namibia. De-bushing activities could have a number of benefits:

- Increased land available for the production of beef and game meat (consumptive use value of food);
- Increased biodiversity. This could impact on use (recreational tourism; indirect use values from associated regulation and maintenance services) as well as non-use values;

- Increased groundwater recharge resulting in associated direct use values for drinking water and provision of water for livestock and wildlife, as well as option values for its future use.

The extent of these benefits would be dependent on the scale and location of any de-bushing activities. There may also be further benefits from the use of any de-bushed material, for example for firewood or crafts. De-bushing would result in an immediate loss of a source of carbon sequestration, but the restoration of rangelands may counteract this to some extent. The benefits of de-bushing would also need to be compared to the costs (for example labour, machinery, loss of carbon sequestration) of doing so. See the *Assessment of the Economics of Land Degradation related to Bush Encroachment in Namibia* (NNF 2016).

3.3 Water

As the driest country in sub-Saharan Africa, water is a very scarce resource in Namibia and human activities and population growth represent a growing pressure on water supplies and the ecosystem services associated with them. These key ecosystem services include the direct consumptive use of water for:

- Provision of drinking water;
- Provision of water for domestic use (cooking, washing, cleaning);
- Provision of water for agriculture (drinking water for livestock, growing crops);
- Provision of water for industrial use (e.g. mining);
- Provision of water for commercial use (e.g. tourism lodges, other services); and
- Provision of water for wildlife.

The use and abstraction of water from rivers may then have further impacts. It could affect the flow and level of water in the river, as well as potentially discharging effluents and polluting the water. This could affect other services, such as the provision of food from fish, wider regulation and maintenance services that support the functioning of the ecosystem (for example the transport of sediments; the dilution, detoxification and filtration of pollutants; and the maintenance of nursery populations and habitats) and cultural services, such as recreational tourism and the aesthetic features of riverine landscapes.

An economic valuation study relating to water may also want to take into account the needs of the Water Accounts that are currently being updated through the ResMob project. Another issue that was raised during the production of the *Inventory* was the abstraction of water from the Kavango River primarily to supply water to population centres such as Windhoek. This could be the basis for an interesting economic valuation study which could consider the impacts of this abstraction (including potential downstream effects in Botswana, including the Okavango Delta) and compare them with the impacts and costs of abstraction and transportation from other sources, such as the Orange River or increased desalination.

3.4 Soil fertility and rangeland carrying capacity

Increasing cattle numbers, in addition to bush encroachment, are putting pressure on rangelands, resulting in overgrazing and land degradation. The economic value of the loss in rangeland productivity is therefore another issue that could be explored. The primary benefit of addressing

overgrazing would result over the medium term from the potential for the increased consumptive use value of meat production as a result of improved soil fertility and the restoration of rangelands. There may also be benefits for the production of crops, wildlife populations, and carbon sequestration.

3.5 Wildlife

The Wildlife Accounts (Barnes et al., 2009) estimated that the wildlife use sector contributed approximately 2.1% to GNP in 2004. The regular updating of the wildlife accounts should be a priority for MET, but in doing so there is also an opportunity to expand the understanding of the economic values of wildlife.

Firstly, the Wildlife Accounts only assess direct use values. They therefore exclude any indirect use values that may be associated with regulation and maintenance services, such as improvements in rangeland quality that may be achieved by shifts from cattle keeping and farming only to mixed-use with wildlife, and indirect use and non-use values from cultural services, for example through representations of Namibian wildlife in international media and existence, and bequest values as evidenced by international donations to protect particular species.

Secondly, when attributing non-consumptive use values to wildlife (i.e. through photographic tourism) there is no distinction between different species. This means that an additional springbok is given the same monetary value in terms of wildlife viewing as an additional black rhino; however in reality there are iconic species which are more likely to attract tourists to a particular area if they know they are there. This is evidenced by the existence of rhino and elephant tracking tours in the north and west of Namibia. Given that it is these iconic species that are most under threat from poaching, understanding the direct use value associated with different species could help to focus conservation efforts on certain species.

Thirdly, there is no assessment of willingness to pay, even for the direct use values. An economic valuation study should not necessarily look only at what people actually pay, but what they would be willing to pay.

Consequently there is scope for further economic valuation studies relating to wildlife. These could take the following form:

- A stated preference study to estimate total willingness to pay with respect to direct use (e.g. wildlife viewing) and non-use (e.g. existence, bequest) values. The estimation of non-use values could be compared with estimates of international donations to Namibian-based charities or NGOs that work on conservation. The stated preference study could also estimate the economic values of the non-consumptive use of different species.
- An assessment of cultural services that relate to Namibian wildlife in international media. This could potentially be achieved by looking at payments made for filming permits and the wider costs of capturing the media.
- An exploration of what impacts increased wildlife numbers have on regulation and maintenance services, for example, those related to rangeland quality. This could require some input from ecologists and rangeland scientists, estimating a production function that relates wildlife land uses to, for example, beef production.

4 References

Aplizar, F. and Bovarnick, A. (2013). *Targeted Scenario Analysis: A new approach to capturing and presenting ecosystem service values for decision making*. UNDP.

Barnes, J.I., Nhuleipo, O., Baker, A.C., Muteyauli, P.I. and Shigwedha, V. (2009). *Wildlife resource accounts for Namibia*, *2004*. Ministry of Environment and Tourism, DEA Research Discussion Paper 79, June 2009.

Bateman, I.J., Mace, G., Fezzi, C., Atkinson, G. and K. Turner (2011). *Economic Analysis for Ecosystem Service Assessments.* Environmental and Resource Economics, 48:177-218.

Brouwer, R., Brander, L., Kuik, O., Papyrakis, E. and I. Bateman (2013). *A synthesis of approaches to assess and value ecosystem services in the EU in the context of TEEB*. TEEB follow-up study for Europe.

Eftec (2009). *Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal*. Report Submitted to Defra.

Fisher, B. et al. (2008). *Ecosystem Services and Economic Theory: Integration for Policy-Relevant Research.* Ecological Applications, Vol. 18, No. 8, pp. 2050-2067.

Namibia Nature Foundation (2016). *Assessment of the Economics of Land Degradation related to Bush Encroachment in Namibia*. MAWF/GIZ Support to De-bushing Project, Windhoek.

Pascual, U. and R. Muradian (2010). *The economics of valuing ecosystem services and biodiversity.* TEEB.

Turpie, J., Lange G-M., Martin, R., Davies, R. and Barnes, J. I. (2005). *Namibia protected areas: Their economic worth and the feasibility of their financing.* Ministry of Environment and Tourism, DEA Research Discussion Paper 73, September 2005.

Turpie, J., Barnes, J.I., Lange, G-M. and Martin R. (2010). *The Economic Value of Namibia's Protected Area System: A Case for Increased Investment*. Ministry of Environment and Tourism Directorate of Parks and Wildlife Management.

UN (2014). *System of Environmental Economic Accounting 2012: Experimental Ecosystem Accounting*. United Nations, New York.

TEEB (2013). *Guidance Manual for TEEB Country Studies*. Version 1.0.

World Travel and Tourism Council (2015). *Travel & Tourism Economic Impact 2015 Namibia*. WTTC.