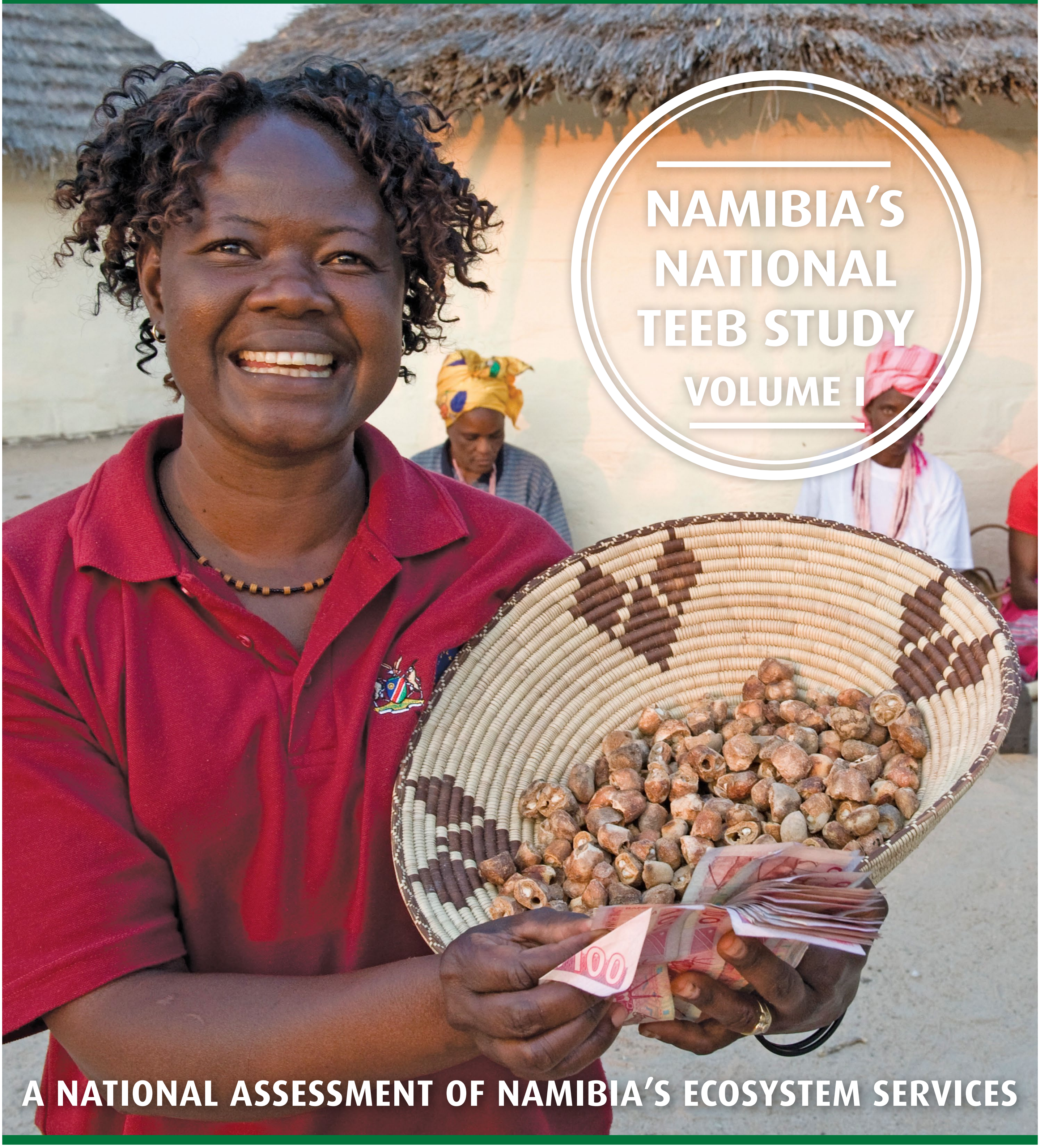
Department of Environmental Affairs

MINISTRY OF ENVIRONMENT AND TOURISM

The Economics of Ecosystems and Biodiversity (TEEB)



NAMIBIA'S NATIONAL TEEB STUDY

VOLUME I

A NATIONAL ASSESSMENT OF NAMIBIA'S ECOSYSTEM SERVICES

Namibia's National TEEB (The Economics of Ecosystems and Biodiversity) Study

The development of strategies to maintain and enhance the protection of ecosystem services in Namibia's state, communal and freehold lands

Volume I: A national assessment of Namibia's Ecosystem Services

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Resource Mobilisation for Biodiversity Conservation

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Department of Environmental Affairs
MINISTRY OF ENVIRONMENT AND TOURISM

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List of Acronyms

CBD	United Nations Convention on Biological Diversity
DEA	Directorate of Environmental Affairs
DVS	Directorate of Veterinary Services, MAWF
FAO	Food and Agricultural Organisation of the United Nations
GDP	Gross Domestic Product
GIS	Graphic Information Systems
GIZ	Deutsche Gesellschaft für internationale Zusammenarbeit GmbH
InVEST	Integrated Valuation of Ecosystem Services and Trade-offs
IPCC	Intergovernmental Panel on Climate Change
KAZA	Kavango-Zambezi Transfrontier Conservation Area
MEA	Millennium Ecosystem Assessment
MET	Ministry of Environment and Tourism
NBSAP2	2nd National Biodiversity Strategies and Action Plan
NDP	National Development Plan
NGO	Non-Governmental Organisation
NNF	Namibia Nature Foundation
NTFPs	Non-timber Forest Products
NSA	Namibian Statistics Agency
PUD	Photo User Days
ResMob	Resource Mobilisation for Biodiversity Conservation Project of the MET
TEEB	The Economics of Ecosystems and Biodiversity
UK NEA	United Kingdom National Ecosystem Assessment
UNFCCC	United National Framework Convention on Climate Change
USD	United States Dollar
WTTC	World Travel and Tourism Council

Preface

The Economics of Ecosystems and Biodiversity (TEEB) study for Namibia was compiled in five volumes.

The first is a national assessment of Namibia's ecosystem services, three volumes are on protected areas, communal and freehold lands, respectively, and the final volume addresses the cross-cutting issue of of conservation hunting in the context of the biodiversity economy.

This volume (I) is a national assessment of Namibia's ecosystem services aimed at identifying and valuing the important ecosystem services being provided by Namibia's ecosystems across different land tenure types.

This desktop study was conducted by Katherine Forsythe, Gwyneth Letley and Dr Jane Turpie from Anchor Environmental Consultants. We are grateful to the ResMob Project for their assistance in collating some of the data used in these analyses.

Volume	Title	Authors
I	A national assessment of Namibia's Ecosystem Services.	Forsythe, K., Letley, G. & Turpie, J.
II	Improving state protected area financing through pricing and institutional changes.	Letley, G. & Turpie, J.
III	Potential for the use of a Payments-for-Ecosystem Services system in Namibia's Communal Conservancies.	Turpie, J., Brick, K., Letley, G. & Maclaren, C.
IV	Incentives for sustainable practices and conservation in Namibia's freehold rangelands.	Turpie, J., Letley, G., Ijambo, B., Venter, R. & Lindeque, P.
V	The value of hunting for conservation in the context of the biodiversity economy	Ijambo, B. & Middleton, A.

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Executive Summary

Introduction

Namibia is home to incredibly unique and diverse biodiversity which underpins many of its important industries including agriculture and tourism. Namibia has demonstrated its commitment to conservation of its biological resources through its policy and legislative frameworks aimed at appropriately managing these resources. While Namibia's current policies have gone a long way towards supporting sustainable use of wildlife and plant resources, ecosystem degradation and the erosion of the natural resource-base can quickly undo many of the gains made over the past 30 years.

The Biodiversity for Biodiversity Conservation (ResMob) Project of the Ministry of Environment and Tourism (MET), in partnership with GIZ is working to improve Namibia's capacity to mobilise additional resources for biodiversity conservation and implement the objectives of the second National Biodiversity Strategies and Action Plan (NBSAP).

The objective of the study is to evaluate the potential of, and develop proposals for, the introduction of specific policy measures in each of the four priority sectors, namely 1) financing of protected areas, 2) the feasibility of payments for ecosystem services in communally conserved areas, 3) conservation efforts and wildlife use on private farms and 4) an analysis of conservation hunting in the context of the biodiversity economy as a form of sustainable use of biodiversity. Underpinning these four work packages is an initial study delineating ecosystem services and their value across the country to inform potential mechanisms by which critical investments can be made.

Volume	Report Title
Vol I	A National Assessment of Namibia's Ecosystem Services.
Vol II	Improving state protected area financing through pricing and institutional changes.
Vol III	Potential for the use of a Payments-for-Ecosystem Services system in Namibia's Communal Conservancies.
Vol IV	Incentives for sustainable practices and conservation in Namibia's freehold rangelands.
Vol V	The value of conservation hunting in the context of the biodiversity economy.

Valuation framework and approach

This volume aims to understand the spatial distribution of the different ecosystem services throughout Namibia in order to prioritise areas for intervention and/or support. It also aims to identify gaps in current understanding and provide a framework for ecosystem valuation that can be updated as newer or more accurate data becomes available.

Ecosystems provide a range of different goods and services that generate value and contribute towards economic production and human welfare. Goods include harvested resources, such as fuel wood and fish. Services are processes that contribute towards economic production or save costs, such as water purification and carbon sequestration, and attributes relate to the structure and organisation of biodiversity, such as beauty, rarity or diversity, and generate less tangible values such as spiritual, educational, cultural and recreational value.

There are numerous different classification schemes, each with their own merits and pitfalls that have been used to classify ecosystem goods and services. For the purposes of the current study we used the more traditional ecosystem service classification approach (i.e. Millennium Ecosystem Assessment and TEEB), which provided the best option as they minimise double-counting and relate to tangible goods and services that can be quantified. We stuck to three categories of ecosystem services, namely provision value of natural resources, amenity value and regulating services. We then mapped the main goods and services within each category and estimated values where possible.

We limited our assessment to ecosystem services supplied by natural ecosystems and discount activities which actively replace or degrade natural ecosystems (e.g. the replacement of ecosystems with crops). We do however consider the

inputs to these activities provided from neighbouring natural ecosystems. For activities where degradation occurs at higher levels of usage (such as grazing and harvesting of natural resources), we only value the service up to the sustainable yield the ecosystem can provide, even if this is lower than actual usage. This was a desktop-based study that relied on available literature, previous valuation studies and mapping exercises, concentrating on rural ecosystems at a broad scale and did not include urban or marine environments. Maps provided in this study are intended to be used for decision making at large-scales; ground-truthing would be required for finer-scale decisions.

The approach taken combines, where possible, both demand and the sustainable supply of ecosystem services to try and establish their economic value. Where there are markets for the services provided by ecosystems, the traded market good or service provides a basis for valuing them. Goods and services with market value are valued as the resource rent which is the surplus value after all costs have been accounted for, i.e. the difference between the price at which the resource can be sold and its respective production costs. For most resources that are harvested directly from ecosystems this production cost may be relatively low compared to the value derived. In all cases where there are markets for goods and services (i.e. provision of natural resources, game, fodder production and tourism) the resource rent approach was used which aligns with the ecosystem accounting valuation approach. Where market prices were not available, estimates were obtained indirectly. Unpriced services were valued by estimating how much it would cost to replace them, or the damages that might be incurred if they were removed.

The static approach to valuing ecosystem services (valuing current state vs. comparing change in value under alternative scenarios), while appropriate for most provisioning services, does have some serious conceptual problems for many of the regulating services. As such, not all regulating ecosystem services were able to be valued during this study, however, for most services the areas where the highest value is likely to occur were identified.

Provision of natural resources

The livelihoods of the majority of Namibians depend heavily on renewable natural resources. Many of these resources are directly consumed for subsistence needs, whereas a few are also used to make products that can be sold or traded. Natural resources include terrestrial resources, freshwater fish, game (for hunting and trophies) and fodder production.

Household demand for terrestrial natural resources such as fuel wood, poles, saw timber, reeds, sedges and palm leaves, wild foods and medicines, wild meat and birds were estimated from the literature, mainly from studies conducted in the Caprivi and Kavango regions. Potential sustainable yields for each of the resources were estimated also based on the literature for the major vegetation types within Namibia. Where estimates of sustainable yields were not available, explicit assumptions were made based on estimates from comparable habitats. We estimated the value of the sustainable yield of natural resources, as far as this was demanded, considering accessibility to resources on different land tenure types and degradation of resources via bush encroachment and clearing for cultivation. The total potential value of terrestrial natural resource use was estimated to be in the order of **N$3 billion per year**. Average value per hectare is highest in the north-central and north-east of the country, where both biological productivity and human population densities are high.

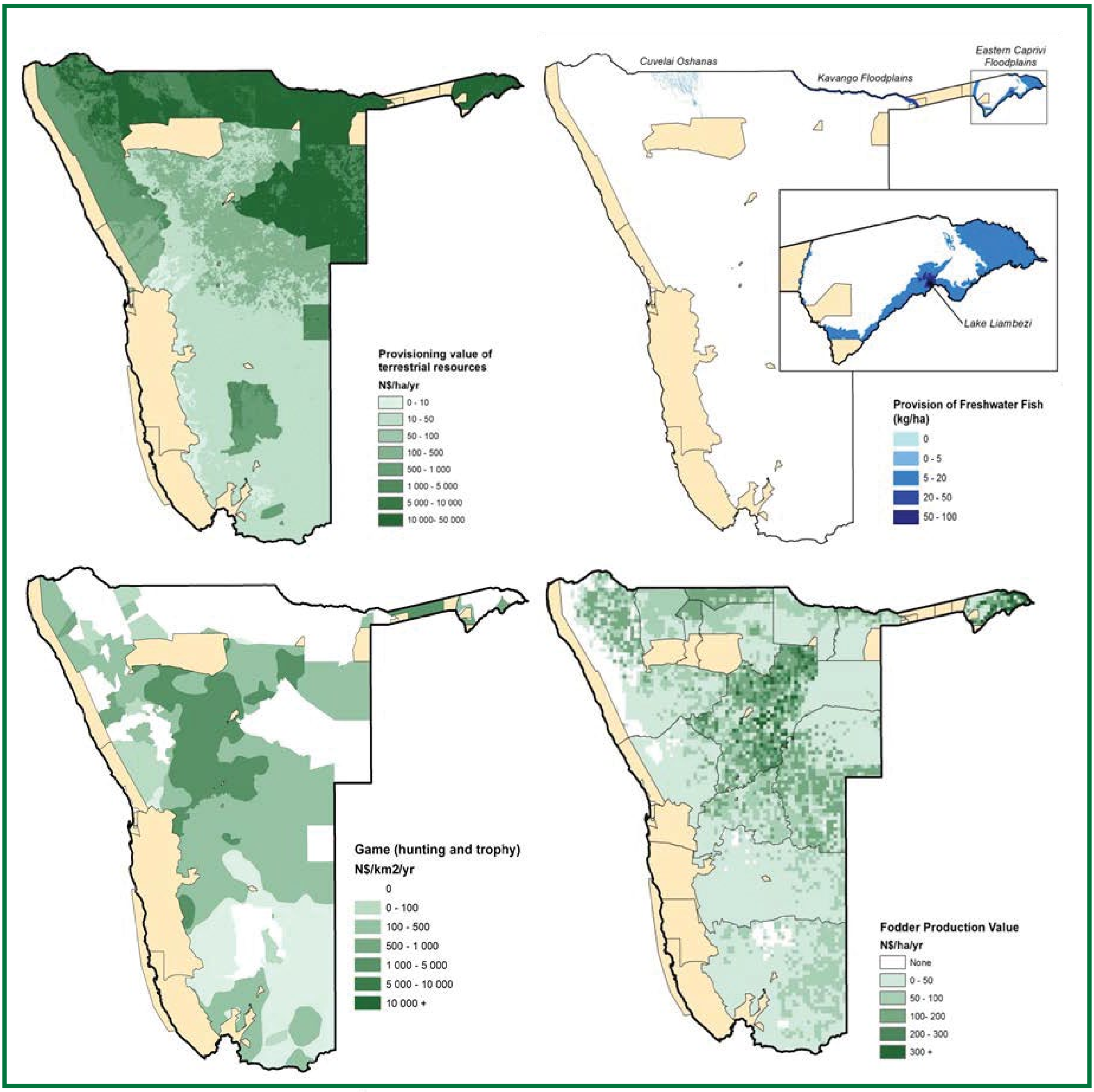
In Namibia inland fisheries are locally important for subsistence and employment especially in the Zambezi region and along the Kavango River. In these areas most households consume fish on a daily basis and the majority of households consider it the most important source of protein. We estimated the maximum sustainable yield separately for each major water resources where fishing occurs. Inland fisheries are estimated to have a value of **N$109.4 million per year**. The Zambezi River and eastern Caprivi floodplains including Lake Liambezi account for two-thirds of this value, contributing N$32.5 and N$33.5 million per year, respectively. Lake Liambezi is the most productive system (when full) and has the highest per hectare values.

Namibia supports significant wildlife populations, which occur mainly outside of protected areas. Wild game species have a number of uses that derive value across the different land-use types in Namibia. Hunting for trophies as well as hunting for meat occur and are permitted to different extents throughout Namibia dependent upon land tenure types. To estimate the potential sustainable supply of game species, for both trophy and meat offtake, we used population estimates for communal and freehold land and applied species-specific sustainable offtakes rates. Applying the estimated resource rent and assuming that the demand for meat offtake was fully demanded and that trophy hunting was only

demanded by the number of permits issued each year, the value of game for meat and trophy hunting was estimated to be approximately **N$182.5 million per year**.

Livestock production in Namibia is an important economic activity. Most livestock in Namibia is free-ranging and relies on natural fodder produced by rangelands. We estimated the annual grazing demand for livestock in Namibia and priced this at the minimum commercial value of fodder. The value of fodder requirement for livestock would produce an overestimate of grazing value in overstocked areas. We estimated the difference between stocking rate and carrying capacity and where the livestock numbers were greater than carrying capacity we only considered the proportion within the carrying capacity. The overall value of replacing fodder production in Namibia was estimated at N$18.6 billion annually. The entire value of replacing fodder throughout the country cannot be assigned to the ecosystem service. If fodder production was priced at replacement value, realistically the industry would collapse, generating a loss of approximately **N$3.8 billion annually**. Fodder production value was highest in the north-central freehold farmlands.

Figure I. The value of provisioning services in Namibia



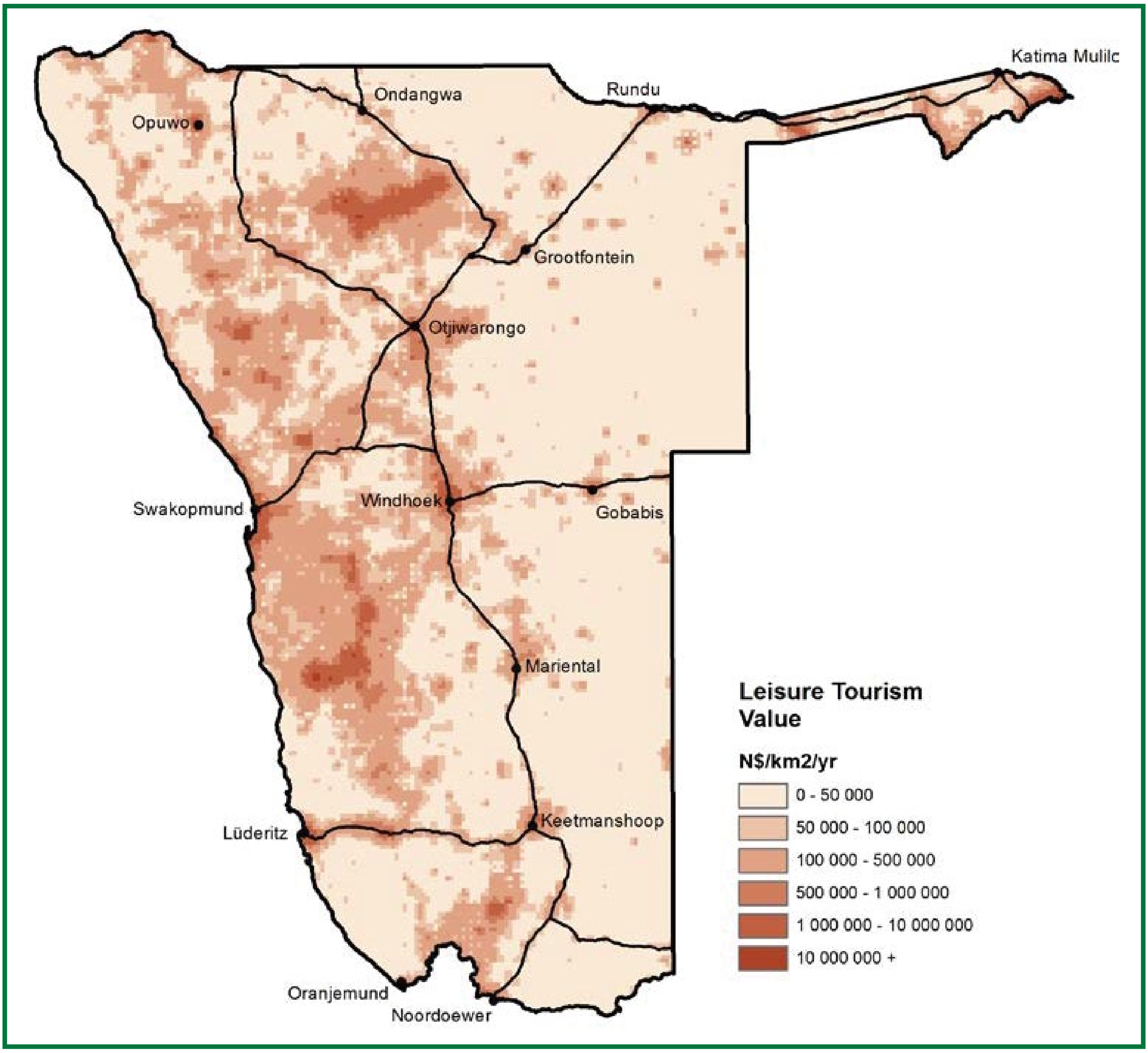
Amenity value

The amenity value of landscapes and ecosystems is derived from combinations of their natural attributes such as size, beauty and rarity, as well as man-made enhancements such as roads, waterholes, viewpoints and other tourism infrastructure. These attributes determine the extent to which each area is suitable or attractive for recreational use, religious use or spiritual fulfilment.

We estimated the distribution of amenity value across Namibia using the distribution of geo-tagged photo data captured in the online photo database Flikr using the InVEST Recreation Model. The distribution of photos correlated well with major tourism routes, showing concentrations around major towns such as Windhoek, Swakopmund and Otjiwarongo, as well as tourism destinations such as Etosha National Park, the Namib-Naukluft Park near Sesriem as well as within Damaraland.

We used data on tourism visits and spending to estimate the tourism value of Namibia's natural areas and mapped this value back to the distribution of photos. The total tourism spending value (leisure and business) across Namibia is approximately N$16.4 billion per annum (WTTC 2014). Using the best available data, we estimate that at least **N$5.2 billion** of this value (36%) is directly attributable to the natural environment.

Figure II. Leisure tourism value (N$/km²/y) in Namibia



Some of the more intangible cultural and amenity values such as scientific and educational values as well as existence value and cultural significance are difficult or impossible to fully value in monetary terms. The value that these services provided however can be important and should be recognised. Namibia's unique and stark landscapes have widespread appeal and potential value, especially in photographs, film and in books. These unique and diverse ecosystems also provide opportunities for research, education and volunteer tourism. These values can sometimes be quantified through assessing people willingness to pay for the existence of Namibia's nature through conservation-related projects. Spirituality can relate to religious values that are held by local indigenous communities or it can relate to the values of those who find spiritual inspiration from nature, or through interactions with nature that occur during daily activities such as collecting natural resources. These cultural values can have large value to individuals' well-being, however are difficult to place a monetary value on.

Regulating services

Regulating services are underlying processes occurring within ecosystems that help underpin other economic activities as well as regulate flows of water, nutrients, sediment and biomass through the landscape to the benefit of populations. Many of these services are however extremely hard to quantify and value. Where possible we present preliminary estimates of values and otherwise describe the different regulating services in order to identify areas where they are likely important within Namibia.

Agricultural support
Natural environments can contribute to agricultural production through pollination and pest control. In Namibia however, most crops are wind pollinated and do not require pollination by animals. Areas which likely benefit from this service are those where land has been cleared for agriculture which are mainly concentrated in the northern communal lands. In addition, areas where irrigation schemes support more diverse agriculture may also be benefiting from both wild pollination and pest control.

Wetlands and flood protection
The occurrence of flooding is often a combination of a multitude of factors, however, having natural floodplains and wetlands upstream can help significantly reduce peak flow volumes and reduce damage. In Namibia floodplain in the Zambezi region and along the Kavango River help regulate flows in downstream countries, but these benefits are not realised within Namibia. The Oshana wetlands in the Cuvelai drainage region help regulate flooding further south, however overgrazing and sedimentation is currently diminishing water storage value and potentially exacerbating flooding related costs in the region.

Sediment retention
Vegetated landscapes have the ability to reduce erosion, retain sediments and topsoil in place, as well as filter surface run-off and remove excess sediment. Erosion and sedimentation are natural processes that play an important role in delivering nutrients to floodplains, estuaries and marine environments. When land degradation occurs, this natural process becomes exacerbated and can lead to the loss of important topsoil as well the delivery of excess sediments into waterways. Excess sedimentation can decrease dam storage and lead to higher treatment costs to purify water. Areas where the natural sediment retention value of vegetation is playing a valuable role would be in the catchments of the major dams.

Water quality
Vegetation in landscapes, as well as in wetlands has the ability to filter-out nutrients and improve water quality downstream. Similar to the sediment retention value, this value is likely being realised in the major dam catchments. In addition, areas in which wetlands exist and are likely offering the service of water quality amelioration include the wetlands and floodplain surrounding the perennial river systems along Namibia's northern and southern borders.

Groundwater recharge
Groundwater is a major contributor to drinking water within Namibia, supplying almost half of the available freshwater. These underground water resources must be recharged from rainfall and other surface waters if they are to be sustainably utilised. Namibia has a mixture of fractured and porous, deep and shallow aquifers. Understanding of groundwater dynamics at a national scale is lacking and connection and flows between aquifers are complex.

Vegetation potentially assists infiltration of rainwater to recharge aquifers by slowing surface run-off and breaking up compacted soils with roots. This is however complicated by the water-use of the plants themselves, which use some of this water. A simplified groundwater model based on estimated sustainable yield (mediated by vegetation, soils and rainfall) and demand based on locations of boreholes indicated that the vegetation on freehold central and southern regions of Namibia contribute to ground water recharge the most.

Carbon storage

Natural systems are understood to make a significant contribution to global climate regulation through the sequestration and storage of carbon in biomass of vegetation. The distribution of carbon storage across Namibia was mapped based on the IPCC-Tier 1 Global Biomass Carbon Map. It was estimated that approximately 1.3 billion tonnes of carbon are stored within Namibia's vegetation. The highest densities occur in the north-eastern parts of the country where dense bush (natural as well as that affected by bush encroachment) occur. The benefit to Namibia of maintaining its ecosystems is the sum of local damage costs avoided and sale of carbon credits to the rest of the world. We used estimates of the global social cost of carbon and disaggregated it to the potential cost that would be borne Africa, and then in Namibia, scaled by an index of vulnerability of climate change. Thus, while the global damage costs that this amount of carbon could produce are over N$2 153 billion world-wide, the damage costs to Namibia resulting from a loss of the carbon stocks nationally might only be approximately **N$38 million** per annum.

See Figure III on the page 15: Spatial distribution of agricultural support services, sediment retention services, water quality amelioration services, flood retention services and the value and spatial distribution of groundwater recharge and carbon storage.

Ecosystem services in relation to land tenure

The total value of ecosystem services was estimated to be in excess of N$13 billion/year, or roughly 9% of Namibia's GDP (World Bank 2016). These ecosystem services were not equally distributed across the country or across the different land tenure types. The main drivers of the distribution of value differed between services and included rainfall (and therefore productivity) as well as human population.

The value of provisioning services such as woody resources, food and medicinal uses were highest in communal areas where there is a higher demand for such services. Other provisioning services like fodder and game meat production were highest on freehold land where high game numbers exist and commercial livestock is the main economic activity. Regulating services like groundwater recharge was mainly related to porous soils as well as demand through the distribution of boreholes and was therefore highest on freehold lands were landholders have sunk boreholes to provide water for cattle. Carbon storage was highest in communal lands which span the high rainfall regions of Namibia where vegetation biomass is the greatest. The distribution of tourism value was high in all land tenure types, but was highest within protected areas.

Table I. Distribution of value of ecosystem services across main land tenure types within Namibia

Ecosystem Service		Freehold land N$	Communal land N$	Protected Areas N$
Provisioning	Woody resources	12 199 064	1 862 132 519	
	Non-woody resources	7 765 720	740 121 237	
	Food and medicines	10 014 286	667 705 857	
	Inland fisheries		109 392 445	
	Livestock fodder	2 281 944 143	1 518 055 857	
	Game (meat)	93 564 949	17 580 000	
	Game (trophies)	77 580 793	2 223 000	
Amenity	Tourism (nature-based)	1 208 450 704	1 812 676 056	2 178 873 239
Regulating	Carbon storage	16 313 745	18 901 891	2 784 362
	Groundwater storage	372 886 114	65 700 607	9 276 612
Total		**4 207 544 776**	**4 080 719 518**	**2 190 934 213**

Degrading processes affecting ecosystem services in Namibia

A number of processes have been identified to affect the supply of ecosystem services throughout Namibia, although these are not evenly distributed throughout the country. The main processes include overgrazing, bush encroachment and over-exploitation of natural resources.

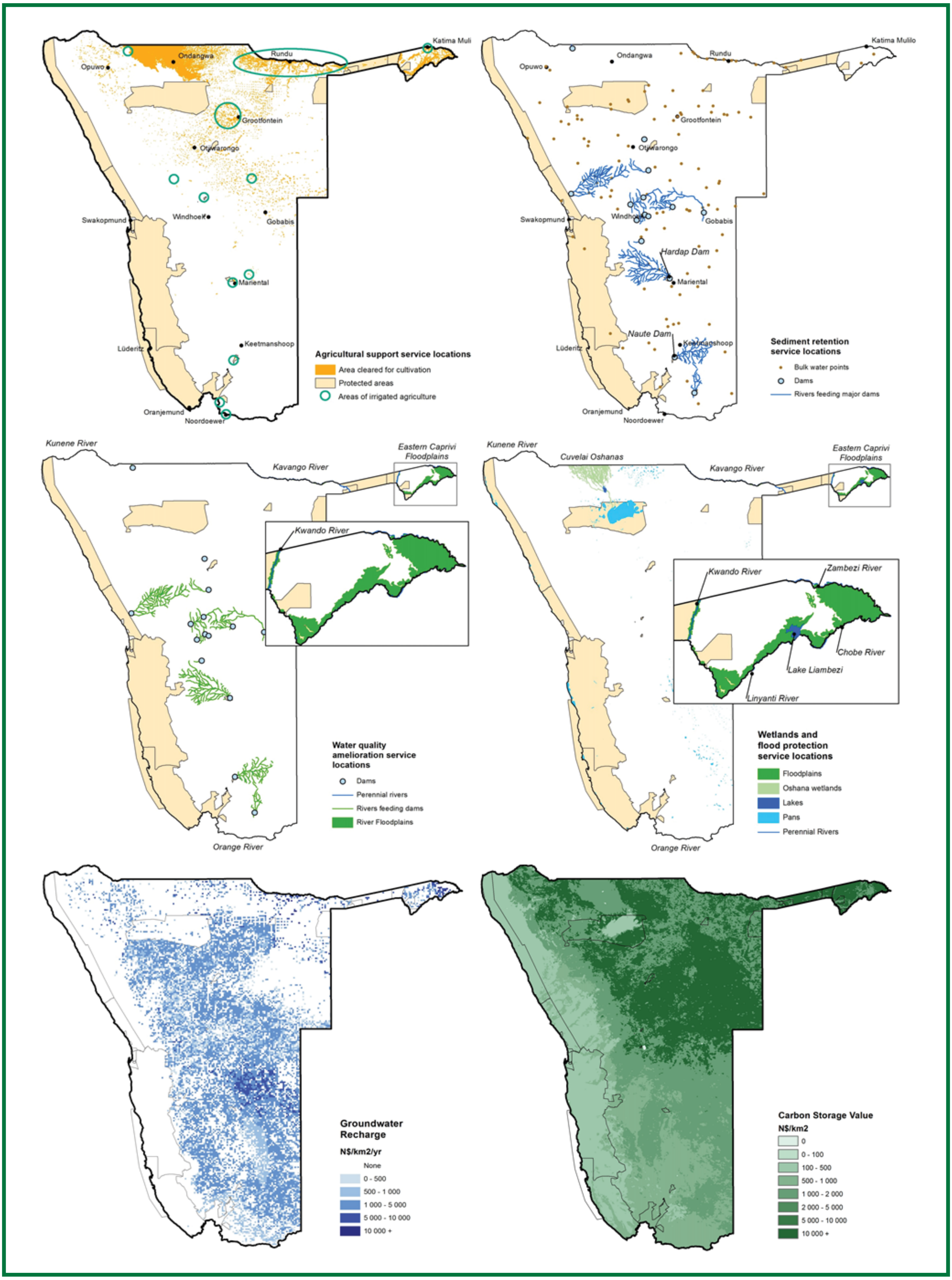
Overgrazing leads to a reduction of carrying capacity for livestock and therefore reduce the value of the important ecosystem service of fodder production. This value was estimated to be one of the highest-valued ecosystem services and there is therefore a lot at stake if overgrazing is left unchecked. The effect of overgrazing also has other ramifications in the ecosystem including reducing the ability of the ecosystem to retain sediments as well as decreasing groundwater infiltration. Overgrazing is currently mainly concentrated in the northern communal lands, especially in the Oshana region. Localised overgrazing is also seen throughout the freehold land across Namibia.

Bush encroachment is another threat to a number of ecosystem services in Namibia. Bush encroachment has the potential to negatively affect grazing capacity, groundwater recharge as well as the provision of some harvested resources. On the other hand bush encroachment could potentially lead to increases in carbon stocks and the provision of woody resources. Bush encroachment is concentrated in the north-central farmlands of Namibia and predominately affects freehold landowners.

Over-exploitation is occurring in many areas where the current demand of resources is greater than the sustainable yield the ecosystem can supply. This problem is almost exclusively occurring in the northern communal regions of Namibia where populations are highest. The value of terrestrially harvested resources was very large in these areas, and so the potentially losses of value here are also considered high.

These degrading processes together have already led to losses in the value of ecosystem services. These processes continue to reduce the ability of the ecosystem to supply ecosystem services in future years and for future generations. As such trying to limit, halt or even reverse the degradation of Namibia's ecosystems should be of a high priority at a national level.

Figure III. Spatial distribution of agricultural support services, sediment retention services, water quality amelioration services, flood retention services and the value and spatial distribution of ground water recharge and carbon storage




Picture: Gys Reitz

1

Introduction

1 Introduction

1.1 Background

Namibia's ecosystems and biodiversity are not only incredibly unique but also extremely important in supporting a large number of Namibian industries, including agriculture and tourism. Namibia is committed to protecting and managing its biological resources and the state has created a policy and legislative framework for freehold farms, communal conservancies and community forests to acquire rights over wildlife, trees and non-timber products and tourism. These rights confer both responsibilities and economic benefits to the legal custodians of these resources. This policy framework has led to ever-increasing areas of land being converted to indigenous biodiversity production systems, including wildlife, tourism and forestry, resulting in a significant increase in wildlife numbers and diversity across the country through effective local management and reintroduction initiatives, and dramatic growth in the contribution of these sectors to the national economy.

While Namibia's current policies have gone a long way towards supporting sustainable use of wildlife and plant resources, ecosystem degradation and the erosion of the natural resource base can quickly undo many of the gains made over the past 30 years. There is a need to understand and highlight the wider costs of ecosystem degradation especially in a country where the welfare of most of its inhabitants are so intricately tied to the health of its ecosystems.

1.2 Project background

The Resource Mobilisation for Biodiversity (ResMob) Project of the Ministry of Environment and Tourism (MET), in partnership with GIZ – commissioned by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) – is focused on making the case for investing in biodiversity conservation.

The overarching goal of the ResMob project is to improve Namibia's capacity to mobilise resources for biodiversity conservation, specifically to enable it to implement the objectives outlined in NBSAP 2. As part of this, the previously commissioned biodiversity expenditure review, carried out by the NNF, demonstrated that biodiversity expenditure in Namibia is expected to decline by almost 25% by 2020 under the business-as-usual scenario.

It is therefore essential to better understand the values of biodiversity, ecosystems and their services in order to inform and be incorporated into national accounts, policy and planning. To this end work has been done on Natural Capital Accounting, delineating Ecosystems and their Services in Namibia and reviewing mechanisms for payments for environmental goods and services. The centre piece of the project will now be national TEEB studies that bring together the arguments for potential mechanisms by which critical investments can be made into key environmental goods and services, in this case protected areas and wildlife, which form the backbone of the tourism and agriculture industries.

Priority sector	Policy issues/measure
National parks	The improvement of the park entrance fee system
Community conserved areas	The introduction of a payments for ecosystem services
Conservation efforts and wildlife use on private farms	The introduction of economic incentives for the sustainable use of game and wildlife on private farms
Conservation hunting as a sustainable use of biodiversity	Conservation hunting as a sustainable use of biodiversity in the context of of the biodiversity economy

1.3 Overall study objectives

The objective of the overall study is to evaluate the potential of and develop proposals for the introduction of specific policy measures for each of the four priority sectors, as summarised below:.

The main part of the study is broken down into four work packages, each addressing one of the above topics. The importance of conservation hunting as a key source of biodiversity finance will also be analysed as a cross-cutting issue in order to analyse it's role within the biodiversity economy in Namibia.

1.4 Aim of the ecosystem valuation component

Demonstrating the economic value of ecosystems and their services is crucial in order to ensure that adequate policies and actions are taken to prevent over-exploitation and degradation of ecosystems and their ability to deliver important ecosystem services. Understanding the spatial distribution of these different ecosystem values also helps prioritise areas for intervention and/or support. It also assists in understanding who the beneficiaries of healthy ecosystems are and therefore who stands to lose the most if these ecosystems are not kept in a functioning state.

The aim of this volume is to produce a nation-wide spatial assessment of ecosystem services. This study provides an opportunity to identify areas with particularly high ecosystem service values. It provides a framework for valuation which can be updated as more accurate data becomes available.


Picture: Gys Reitz

2

Valuation framework and approach

2 Valuation framework and approach

2.1 Classification and valuation of ecosystem services

2.1.1 The definition and classification of ecosystem services

Ecosystems provide a range of 'goods' and 'services' and have 'attributes' that generate value and contribute to human welfare (Barbier 1994, 2011; Table 2.1). The concept of ecosystem goods and services stems from the perception of ecosystems as natural capital which contributes to economic production. Goods include harvested resources, such as fuel wood and fish, services are processes that contribute to economic production or save costs, such as water purification and carbon sequestration, and attributes relate to the structure and organisation of biodiversity, such as beauty, rarity or diversity, and generate less tangible values such as spiritual, educational, cultural and recreational value. Goods, services and attributes are often referred to collectively as 'ecosystem services', or 'ecosystem goods and services'.

Table 1.1 Types of ecosystem services generated by natural systems

Ecological characteristics	Economic characteristics	Services
Stocks of resources	Goods	Grazing Woody resources (fuel wood, timber, poles) Non-woody raw materials (thatching grass, reeds) Wild food and medicinal plants Wild meat and birds
Ecological functions and processes	Services	Carbon sequestration and storage Flow regulation (infiltration, flood attenuation) Water quality amelioration Erosion control and sediment trapping Habitat for organisms useful in pollinating and controlling pests of croplands Refugia/critical habitat for organisms used consumptively or non-consumptively beyond forest areas
Ecosystem characteristics and biodiversity composition	Attributes (aesthetic qualities, biodiversity, rarity, physical features)	Spiritual and recreational values that manifest in property values and tourism value Cultural value Scientific and educational value

The publication of the Millennium Ecosystem Assessment (MEA) in 2003 and 2005 was an important milestone in ecosystem services research and resulted in a significant increase in the number of ecosystem service studies worldwide (La Notte et al. 2017, UN 2017). These studies have contributed to the growing recognition of the importance of valuing natural systems and their incorporation into national accounting systems (Braat & de Groot 2012, La Notte et al. 2017, see section 2.1.3). However, the development of a standardised approach to classify and value ecosystem services remains a serious challenge (UN 2014a, La Notte et al. 2017). Differing interpretations of classification and inconsistency across concepts and terminology has resulted in ambiguity.

A number of conceptual frameworks and classification systems for ecosystem services have been proposed (see Potschin et al. 2016, La Notte et al. 2017). Commonly-used classification systems include the following:

- The Millennium Ecosystem Assessment (2005) grouped ecosystem services into four categories - provisioning services, regulating services, cultural services, and supporting services (comprising the underlying processes which maintain conditions for life on Earth). Inclusion of the latter raised concerns about double-counting;
- The Economics of Ecosystems and Biodiversity (TEEB) classification (2010) refined the distinction between services and benefits, and replaced "supporting services" with "habitat services" (maintenance of life cycles and genetic diversity; La Notte et al. 2017);
- The Final Ecosystem Goods and Services Classification System (FEGS-CS) and the National Ecosystem Services Classification System (NESCS) were proposed by the US Environmental Protection Agency (Landers & Nahlik 2013, US EPA 2015). These focus on benefits and beneficiaries in order to avoid possible double counting in valuation (La Notte et al. 2017). Under the FEGS-CS, processes such as photosynthesis and carbon sequestration are considered intermediate ecosystem services and are excluded from assessment as they "are not directly used by humans" (La Notte et al. 2017); and
- The Common International Classification of Ecosystem Services (CICES; Haines-Young & Potschin 2013, 2017) also focuses on "final" ecosystem services. CICES merges the "habitat services" as described by TEEB with regulating services into a single category called "regulating and maintenance services". CICES broadens the concept of eco system services to include crop and livestock production and their co-benefits such as draught power, as well as abiotic energy. CICES places greater emphasis on the ecological system than FEGS-CS, which focuses on the socio-economic system (La Notte et al. 2017).

The NNF ecosystem services inventory (NNF 2016) used the CICES classification which focusses on final ecosystem services of landscapes including transformed areas. The CICES classification scheme lists over 30 types of abiotic and biotic ecosystem services, and while this classification system might seem more comprehensive, it is generally too broad to be able to quantify, map and value in a study such as this. This study follows the more traditional ecosystem service classification approaches (i.e. Millennium Ecosystem Assessment and TEEB), and focusses on the provision of natural resources, cultural (amenity) services and regulating services supplied by natural ecosystems within the terrestrial realm.

2.1.2 Valuation of ecosystem services

The Total Economic Value (TEV) of an ecosystem comprises direct use, indirect, option and non-use values (Table 2.2). Direct use values may be generated through the consumptive or non-consumptive use of resources. This includes both

Table 1.2 Broad relationships between the concepts of ecosystem services and values

Ecological descriptors	Ecosystem services		Total Economic Value
	Barbier 1994, 2011	Millennium Ecosystem Assessment 2005	
Natural resource stocks	Goods	Provisioning services	Consumptive use value
Ecological functioning	Services	Regulating and supporting services	Indirect use value
Ecosystem structure and organisation	Attributes	Cultural services	Non-consumptive use value
			Non-use value

consumptive (e.g. resource harvesting) and non-consumptive (e.g. bird watching) activities, whether for income, subsistence or recreation. Indirect use values are values generated by outputs from the ecosystems in question that form inputs into production in other areas, or that contribute to net economic outputs in the economy by saving on costs.

These outputs are derived from ecosystem functioning such as water purification and flood attenuation. Non-use values include the value of having the option to use the resources (e.g. genetic) of ecosystems in the future (option value), and the value of knowing that their biodiversity is protected (existence value). Although far less tangible than the above values, non-use values are reflected in society's willingness to pay to conserve these resources, sometimes expressed in the form of donations. The relationships between the concepts of ecosystem services and values are shown in Table 1.2.

2.1.3 Environmental-economic and ecosystem accounting

National accounts track the economic performance of a country using the international System of National Accounts (SNA). However, these fail to account for environmental degradation and resource depletion, or the role of ecosystems and ecosystem condition in delivering benefits to society. This is particularly important in developing countries which depend heavily on natural resources. Although resource accounts have been compiled in many countries including Namibia, e.g. for forestry, these merely record the market value of certain resources as positive contributions to Gross Domestic Product (GDP), and do not capture the full value of the ecosystems from which they are derived.

In 2012, the System of Environmental-Economic Accounting (SEEA) Central Framework was adopted by the United Nations Statistical Commission as the first international statistical standard for environmental-economic accounting (UN 2014a). The SEEA Central Framework, which builds on previous versions of the SEEA, is a conceptual framework that focuses on understanding the interactions between the economy and environment and for describing stocks and changes in stocks of environmental assets.

The SEEA Experimental Ecosystem Accounting (EEA) report complements, and builds on, the accounting for environmental assets as described in the SEEA Central Framework. However, the SEEA EEA accounting approach recognises that individual resources (e.g. timber, soil and water) function in combination within a broader system, linking ecosystems to economic and other human activities with the intention of integrating environmental sustainability, human wellbeing and economic growth and development into one accounting framework (UN 2014b).

In ecosystem accounting, ecosystem services are defined "from the perspective of contributions that ecosystems make to benefits used in economic and other human activity" (i.e. they are contributions that ecosystems make to human wellbeing, UN 2017). The focus for national-level accounting is on final ecosystem services, all of which have a direct link with economic units (i.e. businesses, households and governments It is important to consider that ecosystem accounts do not provide an estimate of welfare value, which includes consumers' surplus.

Rather, they estimate the monetary value of the contribution of ecosystems to economic production and consumption (UN 2017). Within an ecosystem accounting framework values are estimated in terms of the exchange value concepts. This involves using the "residual value" resource rent approach for estimating annual values, which can be interpreted as the annual return culminating directly from the ecosystem asset itself, i.e. the surplus value accruing to the user of an ecosystem asset calculated after all costs have been considered.

Since the Biodiversity Resource Mobilisation (ResMob) Project is focused on making the case for investing in biodiversity conservation with the main goal to improve Namibia's capacity to mobilise resources for biodiversity conservation and to move towards a future goal that includes the mainstreaming of natural capital accounting and valuation of ecosystem services in decision and policy making, the approach used in this study followed the ecosystem accounting framework for valuation as far as possible.

2.2 Scope of assessment

The focus of this study is a nation-wide spatial assessment of ecosystem services. The purpose is to gain an understanding of the distribution of the value of ecosystem services across the country and provides a framework for valuation which can be updated when more accurate data becomes available.

The majority of valuation studies in Namibia have followed the more common ecosystem service classification approaches (e.g. MEA 2005, TEEB 2010). These largely align with the components of CICES, but with some variation. This study only focuses on ecosystem services associated with the biotic elements of ecosystems, i.e. excluding water, minerals and abiotic sources of energy. In addition, we have limited our assessment to ecosystem services supplied by natural ecosystems rather than considering benefits derived from any plant or animal.

While agriculture such as crop growing is valuable in Namibia and is derived from plant life, it is an activity which replaces natural vegetation. For these reasons, we do not consider it an ecosystem service. Free ranging livestock farming, however, makes use of the grass provided by natural ecosystems and is therefore included in this analysis. However, when over-grazing occurs, the natural environment is also actively degraded and the benefit is no longer considered sustainable. We have taken the approach where we only value the services provided by natural ecosystems up until the point where the use of the resource does not detrimentally affect the ability to provide the resource in the future.

Urban ecosystems have different dynamics and work at different scales compared to those in rural areas. For the purpose of this study we have concentrated on rural ecosystem services at a broad scale. In addition the study has not included marine ecosystems. The categories and list of services or groups of services included in this study are shown in Table 1.3.

Table 1.3 The categories and list of ecosystem services included in this study. The services marked with an asterisk (*) were valued

Category	Services
Provisioning services	Livestock fodder*
	Harvested terrestrial renewable resources*
	Supply of game for both trophy and meat offtake*
Cultural services	Amenity value manifested in tourism and recreation activities*
	Cultural and religious value
	Existence and bequest (non-use) values
	Scientific and educational value
Regulating services	Carbon sequestration and storage*
	Water quality amelioration
	Control of erosion and sedimentation
	Flow regulation - groundwater recharge*
	Flow regulation – flood attenuation
	Agricultural support
	Critical habitats/refugia e.g. nursery areas

2.3 Mapping and valuation

This was a desktop study relying on available literature, previous valuation studies and mapping exercises that have been conducted throughout Namibia and across the region. While data often existed at different scales, attempts were made to amalgamate studies done at smaller scales. However, this was not always possible and more consistent datasets over larger areas were favoured. This study builds on the inventory of ecosystem services in Namibia report (NNF 2016) which described ecosystem services by ecosystem type across the country.

It described the services being delivered from these ecosystems and the human activities and drivers of change occurring in each of these ecosystems. This current study expands on this work by trying to quantify the value of different goods and services and also mapping the distribution of this value spatially across the country. The intention being that all maps are to be used to inform decisions at large scales within Namibia. For small-scale decision making, groundtruthing is recommended as data sets used for the assessment may not reflect current or future conditions.

The approach taken here combines, where possible, both demand and the sustainable supply of ecosystem services to try and establish their economic value. Where there are markets for the services provided by ecosystems, the traded market good or service provides a basis for valuing them. Goods and services with market value are valued as the resource rent which is the surplus value after all costs have been accounted for, i.e. the difference between the price at which the resource can be sold and its respective production costs.

For most resources that are harvested directly from ecosystems this production cost may be relatively low compared to the value derived. In all cases where there are markets for goods and services (i.e. provision of natural resources, game, fodder production and tourism) we have used the resource rent approach which aligns with the ecosystem accounting valuation approach. Where market prices are not available, estimates have to be obtained indirectly. Unpriced services can be valued by estimating how much it would cost to replace them, or the damages that might be incurred if they were removed.

This static approach to valuing ecosystem services, while appropriate for most provisioning services, does have some serious conceptual problems for many of the regulating services. Constructing a situation in which the services are removed or non-existent is in itself problematic. Depending on how you define this state (e.g. natural ecosystem replaced by bare ground, monocultures, or paved) you will have hugely differing outcomes on how the regulating service is delivered. It is much more useful and informative to rather compare relative changes to the service between different possible future scenarios such as different policies and/or levels of ecosystem degradation.

As such, not all regulating services could be valued during this study, however, for most we were able to identify the areas where the value is likely to occur.

3

Provision of natural resources

3 Provision of natural resources

3.1 Overview

The provisioning value provided by natural systems was estimated as the value of the sustainable yield of natural resources, as far as this is demanded. Terrestrial and freshwater ecosystems provide a number of living and non-living resources which are harvested for raw materials, food and medicine. The livelihoods of the majority of Namibians depend heavily on renewable natural resources. At a national level it has been estimated that 33% of total household consumption in rural areas comes from wild foods and products (Jones 2003).

Households in the Zambezi, Omusati, Ohangwena, Oshikoto, Oshana and Kavango regions are the most dependent on natural resources while those in the Khomas, Erongo and Karas regions are the least dependent. In most parts of the Zambezi Region rural communities rely on wild harvested foods for at least 50% of their sustenance (Jones 2003). This section of the report estimates the provisioning value of natural habitats, taking factors influencing supply and demand into account as far as possible.

The most important natural resources that are harvested include reeds and thatching grass, fuel wood, poles, saw timber, wild plant foods and medicines, game and fish. Many of the resources such as the collection of fuel wood and thatching grass provide basic subsistence needs and are considered core activities undertaken by most rural households. However, some resources are used to provide other household goods such as palms and reeds which are used for baskets and mats, timber for construction and wild fruits and vegetables for food and medicine.

These resources are not always collected by all households, providing opportunities for bartering, sale and enterprise development (Ashley & La Franchi 1997). A number of indigenous plants have become commercialised in Namibia, providing further diversification and alternative sources of income for rural households.

The use of natural resources has been studied to varying degrees in Namibia. The most abundant and comprehensive studies have been conducted in the Zambezi (Caprivi) and Kavango regions as well as the densely populated areas of the Cuvelai Drainage. Most of these studies included household surveys to estimate resource demand and harvesting levels whilst others only included a qualitative description of natural resource use. There is far less information about the availability and use of natural resources by indigenous people in the more arid, sparsely populated southern and western regions of Namibia.

However, the commercialisation of various indigenous plant products from these regions has resulted in an increase in the amount of information available pertaining to the use and distribution of particular resources. Furthermore, while such studies can provide estimates of current use, this use is not necessarily sustainable. Snapshot estimates can therefore provide distorted estimates of value. Ideally, direct use value should be estimated based on a combination of expected demand and estimated sustainable yields. However, in some cases, the only available data are on actual harvests.


Picture: Ralf Bäcker

Available information on sustainable yields, market prices and input prices for different resource types were obtained from the literature, using locally-sourced information as far as possible (see Table 6.1). The vegetation types and local pressures were taken into account in estimating sustainable yields of the different resources. The estimated supply capacity of natural areas was then mapped using GIS. Land use typologies and census population data were used to estimate the general level of demand, taking access constraints into account. In other words, no value was assigned to protected areas or areas that would not be accessible to potential users. A map of demand typologies (based on explicit assumptions outlined below) was superimposed onto the current supply capacity to determine the current provisioning value in terms of aggregate net income to households associated with specific habitats in Namibia.

Table 6.1 Summary of available information in the supply and demand of natural resource use in Namibia

Natural Resource Harvesting	Available Information
Natural resource use	• Scovronick et al. (2007) conducted a socio-economic baseline survey of selected communities within the Kavango-Zambezi (KAZA) Transfrontier Conservation Area. This included estimates of natural resource harvesting.
	• Turpie & Egoh (2003) conducted a comprehensive study on the contribution of natural resources to rural livelihoods around Lake Liambezi and Bukalo Channel in eastern Caprivi.
	• Ashley & La Franchi (1997) examined livelihood strategies of rural households in Caprivi with estimates of use and value.
	• Lannas & Turpie (2009) valued the provisioning services (hunting, livestock, water use, resource harvesting) of two wetlands, one in Lesotho and one in Cape Town.
Wildlife	• Game counts by region and by conservancy (NACSO)
	• Barnes et al. (2005) Namibian wildlife accounts provide detailed information about the consumptive use of wildlife and sustainable offtake rates
	• Lindsey (2011) provided an analysis of game meat production and wildlife-based land uses on freehold land in Namibia. This included wildlife population estimates and biomass estimates.
	• Erb (2004) assessed consumptive wildlife utilization as a land-use form in Namibia
	• Kaschula & Shackleton (2009) estimated the quantity and value of wild meat offtake in a rural village in the Eastern Cape, South Africa
Non-woody raw materials (grasses, reeds, sedges & palm leaves	• Mmopelwa & Blignaut (2009) estimated the direct use values of selected vegetation resources – (grass, reeds, palm leaves, wild fruits and fuel wood) in the Okavango Delta Wetland
	• Gunson (1999) estimated the sustainability of use and economic valuation of wetland plant resources in the Eastern Caprivi floodplains, Namibia.
Wild plant foods and medicines	• Cole et al. (2014) The Commercialisation of Indigenous Natural Plant Products in Namibia contains details about the most important INPs – their distribution, yields, harvesting rates, and prices.
	• Wynberg (2004) discusses achieving a fair and sustainable trade in Devil's Claw and provides information about yields and plant densities.
	• Botelle (2001) documented the use of marula in north-central Namibia and estimated fruit yields.
	• Galloway (2014) conducted a comprehensive study on the impacts of commercialising Commiphora wildii in conservancies in north western Namibia with estimates of plant distribution and harvesting levels.
	• Nott (2010) monitored and researched the harvesting patterns of Commiphora and other high value plants in Kunene region of Namibia.
	• Cheikhyoussef et al. (2011) described the use of certain indigenous plants for medicinal and other purposes by local communities in Namibia, with a focus on the Oshikoto region.
	• Den Adel (2002) described the use of marula products for domestic and commercial purposes by households in North-Central Namibia.
	• Musaba & Sheehama (2009) described the socio-economic factors influencing harvesting of Eembe (Berchemia discolor) wild fig fruits by communal house holds in the Ohangwena region, Namibia.
	• Ngorima (2006) estimated sustainable use of Marula (Sclerocarya birrea) in the Savannah woodlands of Zvishavane District, Zimbabwe.
	• Ito (2005) described changes in the distribution of the Nara plant that affect the life of the Topnaar people in the lower Kuiseb River, Namib Desert.
	• Chinsembu et al. (2011) described the medicinal properties of indigenous plants from the Kavango region.

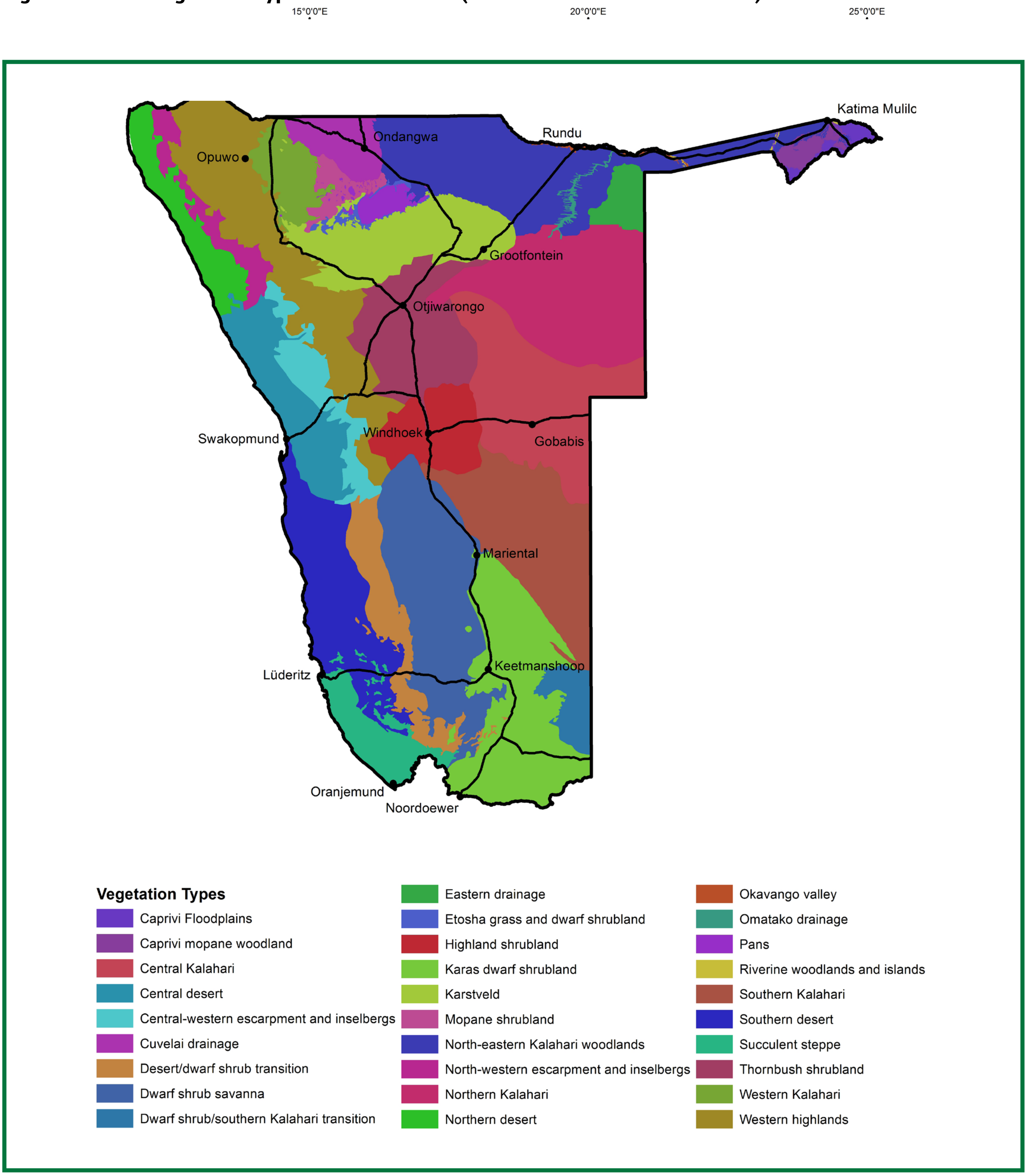
Natural Resource Harvesting	Available Information
	• Grote (2003) described the harvest and trade of Devils Claw and its importance to the indigenous people of Namibia
	• Turpie et al. (2007) estimated the consequences of changing land use in Drakensberg grasslands, South Africa. Value and sustainable harvesting rates estimated for medicinal plants and grasses.
	• Shackleton et al. (2002b) estimated the direct use values of non-timber forest products from three rural villages in the Kat River Valley, South Africa.
	• Shackleton et al. (2007) estimated the direct use values of non-timber forest products from two villages on the Transkei Wild Coast.
	• Cocks & Wiersum (2003) documented the significance of plant diversity in rural livelihoods in the Eastern Cape looking at uses of NTFP's, amounts harvested and their value.
	• Shackleton & Shackleton (2004) reviewed the importance of NTFP's in rural livelihood security in South Africa.
	• Twine et al. (2003) estimated the direct-use values of savannah resources used by rural households in Limpopo, South Africa.
	• High & Shackleton (2000) estimated the value of wild and domestic plants in home gardens In a rural village in Bushbuckridge in the Lowveld of South Africa.
	• Stack et al. (2003) provided mopane worm utilisation data in southern Africa and the importance of mopane worms to household livelihoods.
	• Thomas (2013) assessed the sustainable harvesting and trading of mopane worms in Northern Namibia
	• Potgieter et al. (2012) provided data on distribution, nutritional value and yields.
Fuel wood and poles	• MacGregor (2007) estimated forest resource use and how forest resources contribute to rural livelihoods in the north-central regions of Namibia.
	• Barnes et al. (2005) Namibian forestry accounts provide detailed information about tree volumes and sustainable yields
	• Shackleton (1993) estimated fuel wood harvesting and sustainable utilisation in communal land and in protected areas in the lowveld, South Africa. Information about fuel wood harvesting rates and sustainable yields.
	• Luoga et al. (2000) categorised different uses of resources and quantified the amount of wood used for firewood and building poles in miombo woodlands in eastern Tanzania.
	• Dovie et al. (2002) estimated direct use values of woodland resources consumed and traded in a rural village in South Africa. Information on fuel wood harvesting and prices.
	• Dovie et al. (2004) assessed the fuel wood crisis in Southern Africa by relating fuel wood use to livelihoods in a rural village. Information on fuel wood harvesting and prices.
Fish	• Simasiku (2014) assessed the fishery on Lake Liambezi providing estimates of catches, effort and yields.
	• Tweddle et al. (2011) reported on the management of the fishery on Lake Liambezi and associated floodplains by the community as part of the Zambezi/Chobe River Fisheries Resources Project.
	• Tvedten et al. (1994) compiled a socio-economic background study into the freshwater fisheries and fish management in Namibia.
	• Purvis (2002) reported on fish and livelihoods on the eastern floodplains in the Caprivi with information about fishing activities, effort and management of the fishery.
	• Shapi (2012) evaluated community-based fishery management approaches at Muyako, Lake Liambezi in the Zambezi Region.
	• Van Der Waal (1991) surveyed the fisheries in Kavango region, Namibia with information about fishing techniques, fishing effort and annual yields.
	• Tvedten (2002) described the freshwater fisheries in the Caprivi.
	• Sandlund & Tvedten (1992) conducted a pre-feasibility study on Namibian fresh water fish management, providing a review of the socio-economic and biological status and management and legislation of the freshwater fishing sector.

3.2 Approach

Potential aggregate household demand for all natural resources was estimated for the following resources; fuel wood, poles, saw timber, reeds, sedges and palm leaves, wild foods and medicines, wild meat and fish. Data on sustainable yields for each resource and habitat type were obtained from the literature as far as possible. The major vegetation types within Namibia are shown in Figure 3.1.

These were grouped into 14 broader categories and the sustainable yields and prices for all resources were assigned to each vegetation category based on information from collated studies. Where estimates of sustainable yields were not available, explicit assumptions were made based on estimates from comparable habitats. The criteria and assump-

Figure 3.1 Vegetation types within Namibia (Source: Mendelsohn et al. 2003)



tions used to determine sustainable yields were based on information collected from relevant studies carried out within Namibia. Where data were not readily available for Namibia, studies from southern Africa and further afield were used. Average prices for each of the natural resources were obtained from the literature or based on expert opinion and inflated to 2016 prices.

In addition, a number of natural resources are harvested for commercial purposes. These include harvests of indigenous natural plant products (i.e. natural plant products harvested for commercial purposes to be used as ingredients in cosmetic, medicinal or food applications), for which value estimates were taken from Cole et al. (2014). While this entire value is not necessarily achieved as there are some costs incurred by harvesting these resources, it has been estimated that there is less than a 5% difference between net and gross value of harvested resources within the Caprivi region (Turpie & Egoh 2003). We have therefore only reported the gross value assuming negligible difference between the two.

While ecosystems throughout Namibia have the potential to supply services, not all of the services are actually demanded. In many areas, the low population densities mean that less than the sustainable yield is actually being utilised. There are however certain areas of high population densities were the current demands exceed that which the ecosystems can sustainably supply. It is in these areas where over-exploitation and degradation often occurs.

In order to include these demand dynamics into our spatial assessment we used the number of households in traditional dwellings within each region (Namibia Census Data 2011) as an indication of the number of households that would be harvesting natural resources from the surrounding ecosystems. We then used estimates from studies conducted within Namibia (see Table 6.1) on the percentage of rural households harvesting different types of resources and the average amount of resources being harvested.

This provided an estimate of the actual amount of different resources being harvested. We then compared this to the sustainable yield calculated for each region. If the sustainable yield was greater than actual use then the value of actual use was taken and if the value of the actual use was higher than the sustainable yield, then the sustainable yield was used.

It was conservatively assumed that no resources could be accessed in protected areas (the typical policy), that 10% could be accessed in private lands, and that all resources were accessible in communal land areas (Figure 3.2). Additionally to try an incorporate the degradation of ecosystem service occurring in bush encroached areas and areas that are cleared for cultivation, degradation factors were applied within these areas. In areas that were cleared for cultivation, only 10% of the value was realised, whereas in areas that were bush encroached the value of woody resources was increased by between up to 25% and other resources was decreased up to 50%, depending on the bush density. Final values were distributed using the carbon density map to give areas with higher vegetation density more value than those with sparse vegetation.

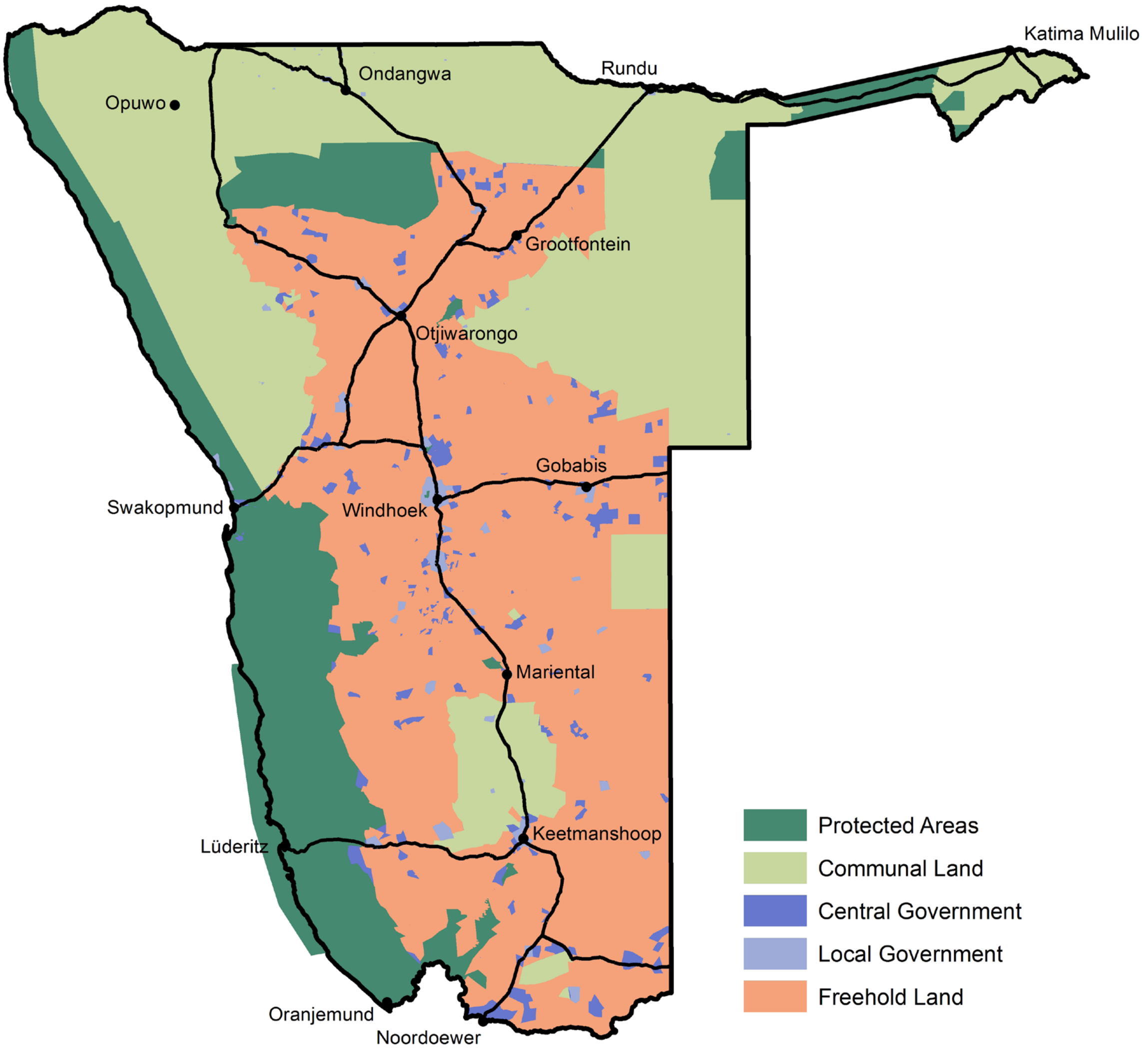
3.3 Terrestrial resources

3.3.1 Woody resources

Fuel wood is a dominant source of energy used for cooking and heating in rural households in Namibia. Within the more rural areas of Namibia, the majority of households live without a direct electricity supply. Due to limited financial resources in these rural areas, households rely on fuel wood as a cheaper alternative to electricity and paraffin. Wooden poles are harvested predominantly in the rural central and north-eastern areas of the country, for the construction of houses, fences and for other building infrastructure. Saw timber is harvested mainly in the Kavango, Zambezi and Ohangwena regions where species such as Teak, Kiaat, African Rosewood, Mopane and Wild Syringa occur.

Total woody resource volume for Namibia is an estimated 257 million m3 (Barnes et al. 2005). The country's highest wood stocks are found in the Kavango region (34%), followed by Oshikoto (17%), Otjozondjupa (16%), Zambezi (12%), Ohangwena (8%) and Omaheke (6.5%, Barnes et al. 2005). The remaining seven regions (Erongo, Hardap, Karas, Khomas, Kunene, Omusati, and Oshana) contain only 6% of total wood stocks (Barnes et al. 2005).

Figure 3.2 Broad categories of landownership across Namibia (Source: Mendelsohn et al. 2003)



The national forest inventory which was completed in 2004 and used to develop a set of forest resource accounts for Namibia (see Barnes et al. 2005) was used here to estimate the potential sustainable yield of woody resources. This involved developing physical accounts for national natural forest assets, which include information on the standing volumes of woody resources in each administrative region of the country.

The amount of standing woody volume that was physically utilisable was assumed to be 90% for fuel wood and 15% for poles (Barnes et al. 2005), allowing for a component of the standing volume to be assumed unsuitable for harvesting. The actual use of woody resources was determined using average household harvesting rates and the average percentage of households participating in the collection of woody resources. It was assumed that each harvesting household collected on average 2920 kg of fuel wood and 500 kg of poles per year. Oshana was the only region where fuel wood and poles were 100% demanded.

Actual use estimates were not available for saw timber and because it is only found in three regions, the sustainable yield as presented in Barnes et al. (2005) was used. Woody resources were valued by using prices of fuel wood, poles and saw timber in Namibia, as provided by Barnes et al. (2005). Prices were adjusted to 2016 Namibian Dollars. A price of N$1233 per m^3 for fuel wood, N$1029 per m^3 for poles, and N$11 200 per m^3 for saw timber were used.

A total of 570 000 m³ of fuel wood and 97 500 m³ of poles was estimated to be the sustainable output (as far as it is demanded) per year in Namibia, with an estimated total value of N$634.5 million and N$90.6 million, respectively (Table 3.2).

The average value per hectare for fuel wood across Namibia is N$31 and for poles is N$4. A total of just over 100 000 m³ of saw timber can be sustainably harvested in the Zambezi, Kavango and Ohangwena regions, with an estimated annual value of N$1.1 billion (Table 6.2). Therefore, the total annual value for woody resources is estimated to be about **N$1.9 billion**.

Table 3.2 The estimated sustainable outputs, price, total value (N$ million/year) and average value per ha (N$/ha) of woody resources in Namibia

Woody resource	Sustainable output (m³/y)	Price (N$/m³)	Value (N$ million/y)	Avg. value per ha (N$/ha)
Fuel wood	569 498	1 233	634	31
Poles	97 374	1 029	91	4
Saw Timber	102 727	11 188	1 149	151
TOTAL	**769 599**		**1 874**	

3.3.2 Non-woody raw materials

Non-woody raw materials include grasses, reeds, sedges and palm leaves. These materials are harvested mainly for construction purposes and for the production of crafts. Grasses are harvested by most, if not all, households for home consumption as well as for sale, whilst reeds, palm leaves and papyrus tend to be harvested by fewer households and are generally bartered and sold.

Grasses are an essential construction material across most of rural Namibia, for thatching and fences as well as for household items such as baskets and brooms. Grasses are generally harvested from river banks, floodplain grasslands, woodlands and mulapos in the central-north and north-eastern regions of Namibia, and from sparse grassland, shrub-land and woodland habitats in the drier western and southern regions. Bundles of grass vary in size from 45 - 85 cm with weights of 4.5 - 10 kg being the most common (Turpie & Egoh 2003, Scovronick et al. 2007, Mmopelwa et al. 2009). Turpie & Egoh (2003) estimated that on average 85% of households in the eastern Caprivi harvest thatching grass with an average annual harvest of 1820 kg per harvester household. Excluding Katimo Mulilo, Scovronick et al. (2007) estimated that 57% of households in Kavango-Zambezi (KAZA) Transfrontier Conservation Area harvested an average of 350 kg of thatching grass per household per year. Mmopelwa et al. (2009) found on average that 63% of households in the Okavango Delta harvested 1630 kg of thatching grass per household per year. Den Adel (2002) conducted household surveys in north-central Namibia and found that 98% of surveyed households used thatching grass, however the amount of grass harvested was not quantified.

Reeds are harvested for construction materials in the form of fencing or to construct ceilings and for making mats and fishing equipment (Turpie & Egoh 2003, Scovronick et al. 2007, Mmopelwa et al. 2009). Reeds are most abundant surrounding lakes, rivers and other wetlands and therefore tend to be more plentiful in higher rainfall years (Scovronick et al. 2007). Since reed beds are located at the edge of perennial wetlands and rivers, only villages in close proximity to these wetlands have ready access (Turpie & Egoh 2003). Mmopelwa et al. (2009) describe how villagers who live further away from harvesting sites will often migrate and stay in these areas for up to two and a half months at a time.

The percentage of harvesting households therefore varies considerably depending on access to the resource. In the eastern Caprivi and along the Okavango River where reed beds are abundant, the number of households partaking in reed harvesting is much higher than those households located in the central Caprivi or in areas where perennial wetlands are few. Turpie & Egoh (2003) estimated that in the eastern Caprivi 32% of households on average harvested reeds with an estimated annual yield of 828 kg per household. Scovronick et al. (2007) found that on average 47% of households in the KAZA Transfrontier Conservation Area harvested reeds with an average harvest of 242 kg per household. In the Okavango Delta the estimates were higher with 68% of households partaking in harvesting and an average of 1704 kg harvested per harvester household each year (Mmopelwa et al. 2009).

Sedges tend to be more difficult to obtain than reeds because of their more restricted habitat requirements, usually requiring perennial inundation (Turpie & Egoh 2003). Papyrus is the preferred material for making sleeping mats and therefore almost all sleeping mats are purchased or made from purchased papyrus which is harvested by women from villages in close proximity to the Zambezi River and wetlands east of Katima Mulilo in the Zambezi Region. It is unlikely that papyrus is readily available in areas outside of the Zambezi Region.

In the eastern Caprivi an average of 120 kg of papyrus were harvested per harvester household and 6% of households were estimated to be harvesting this resource (Turpie & Egoh 2003). Scovronick et al. (2007) estimated that 13% of households in the Caprivi harvested papyrus with an estimated annual harvest of 63 kg per harvester household.

Palm leaves are used to make baskets and to tie grass and reed bundles. Palm trees are found around floodplain grasslands and savannas. They are most abundant in the north-central, Kavango and Zambezi regions. Scovronick et al. (2007) found that only a small and relatively uniform proportion of households across the KAZA study area harvested and traded in palm leaves, with 14% of households harvesting an average of 2.6 kg of palm leaves per harvester household per year. Turpie & Egoh (2003) estimated that in the eastern Caprivi 72% of households harvested palm leaves with an average of 1 kg per harvester household. It was estimated that 30% of households in the Okavango Delta harvested palm leaves with an average of 2.2 kg per harvester household per year.

Sustainable yield estimates were based on information from Mmopelwa et al. 2009, Scovronick et al. (2007), Twine et al. (2003), Turpie et al. (2007) and Turpie & Egoh (2003). The average sustainable yield for harvesting thatching grass was 24 kg/ha/y, for reeds and sedges was 70 kg/ha/y and for palm leaves was 0.015 kg/ha/y. It was estimated that the sustainable output of non-woody raw materials in Namibia, as far as these resources are demanded, is just over 41 000 tonnes with a total value of **N$748 million** per year (Table 3.3). Thatching grass contributes 58% to this value and reeds and sedges contribute 41%.

Table 3.3 The average yields, sustainable outputs and total value (N$ million/year) of non-woody raw materials in Namibia

Woody resource	Sustainable output (m^3/y)	Price (N$/$m^3$)	Value (N$ million/y)	Avg. value per ha (N$/ha)
Thatching grasses	30 952 403	14	433.3	29
Reeds and sedges	10 332 360	30	310.0	74
Palm leaves	65 465	70	4.6	10
TOTAL	**41 350 227**		**747.9**	

3.3.3 Wild foods and medicines

Wild foods and medicines include wild fruits and vegetables, nuts, berries, roots, bulbs, bark, leaves and mopane worms that are collected to supplement diets and provide traditional medicines. The harvesting of wild meat for subsistence purposes is also included here, with small mammals, reptiles and birds being the most popular wild meats that are harvested on a regular basis. The use of wild foods and medicines varies spatially and temporally across the region according to the availability of resources, economic status, agricultural potential and yields, and cultural patterns (Ashley & LaFranchi 1997). The collection of wild foods and medicines can be a seasonal staple, a regular dietary supplement, or only to buffer against drought. Many of these resources are collected to be exchanged or sold and are therefore important for households with low crop outputs (Ashley & LaFranchi 1997).

Wild plants and medicines are collected from a number of different vegetation types within Namibia and include, for the most part, bark, water lilies, wild spinach, roots, small fruits and berries. In the eastern Caprivi, Turpie & Egoh (2003) found that 79% of households collect wild plant foods and medicines with an average of 278 kg per harvester household. Mmopelwa et al. (2009) recorded that 34% of households in the Okavango collected wild plants and medicines with an average of 128 kg per harvester household. Musaba & Sheehama (2009) found that about 80% of households in the Ohangwena region collected wild plants and medicines but the average household harvest was lower at 57 kg. There is very little quantitative information on sustainable yields of wild foods and medicines. For medicinal plants, Mander (1998) estimated that yields of 0.78 kg/ha/y were possible in woodlands and grasslands of KwaZulu-Natal,

and Turpie et al. (2007) estimated that medicinal bulbs and herbs could be harvested in the Drakensberg grasslands at a sustainable rate of 20 kg/ha/y. Mmopelwa et al. (2009) estimated that yields of 1.2 kg/ha/y were possible in the Okavango. An average of these sustainable yield estimates was used and scaled appropriately to the different habitat types, with forests and woodlands having higher yields than grasslands and shrubland. The sustainable yield varied from 0.22 kg/ha/y in dwarf shrubland to 10.4 kg/ha/y in forests, at a price of N$22/kg.

Mopane worms feed mostly from leaves of the mopane tree (Colophospermum mopane). These woodlands cover about 77 000 km^2 of northern Namibia (Thomas 2013). They are an important food source for the local people living in these regions. The average household harvest based on studies in Zimbabwe, Namibia, Botswana and South Africa was estimated to be 150 kg/household/y. A sustainable yield of 14.6 kg/ha/y was applied, taken from a study conducted in Malawi (Potgieter et al. 2012).

Traditional households are known to hunt for wild meat and birds. The most commonly hunted species include spring hares, cane rates, squirrels, bush pigs, and small rodents. Waterbirds such as duck, geese, and cormorants are hunted in wetlands, floodplains and permanent water areas. Upland birds such as small bush birds and partridges are also hunted. In the eastern Caprivi 64% of households were estimated to hunt for wild animals and birds with an average harvester household hunting 97 kg of wild meat per year (Turpie & Egoh 2003). Studies of wild meat harvesting (mainly mammals and birds) have found offtake rates in the region of 209 kg/km^2/y in coastal regions of South Africa (Shackleton et al. 2007), 268.6 kg/km^2/y or 3 kg/person/y in the inland communal areas of the Eastern Cape (Kaschula & Shackleton 2009) and 151 kg/km^2/y in the Kat River Valley (Shackleton et al. 2002b). In all cases the harvesting rate did not appear to be unsustainable. Based on these we estimated a sustainable yield of 215 kg/km^2/y for forests and riverine floodplain habitat, and 104 kg/km^2/y (an average of the lower two estimates) for woodlands and grasslands. An average price of N$18 per kg was used based on prices taken from the above listed studies.

The value of the sustainable output of all wild foods and medicines was estimated to be **N$676 million** per year (Table 3.4). The sustainable yield of wild plants and medicines was estimated to be just over 15 000 tonnes/y with a value of N$331 million, mopane worms have an estimated annual value of N$177 million, and wild meat and birds has an estimated annual value of N$168 million.

Table 3.4 The average yields, sustainable outputs and total value (N$ million/year) of wild foods and medicines in Namibia

Wild food and medicines	Sustainable output (kg/y)	Price (N$/kg)	Value (N$ million/y)	Avg. value per ha (N$/ha)
Wild plants and medicines	15 021 195	22	330.5	19
Mopane worms	9 850 597	18	177.3	10
Wild meat and birds	4 807 899	35	168.3	37
TOTAL	**29 679 691**		**676.1**	

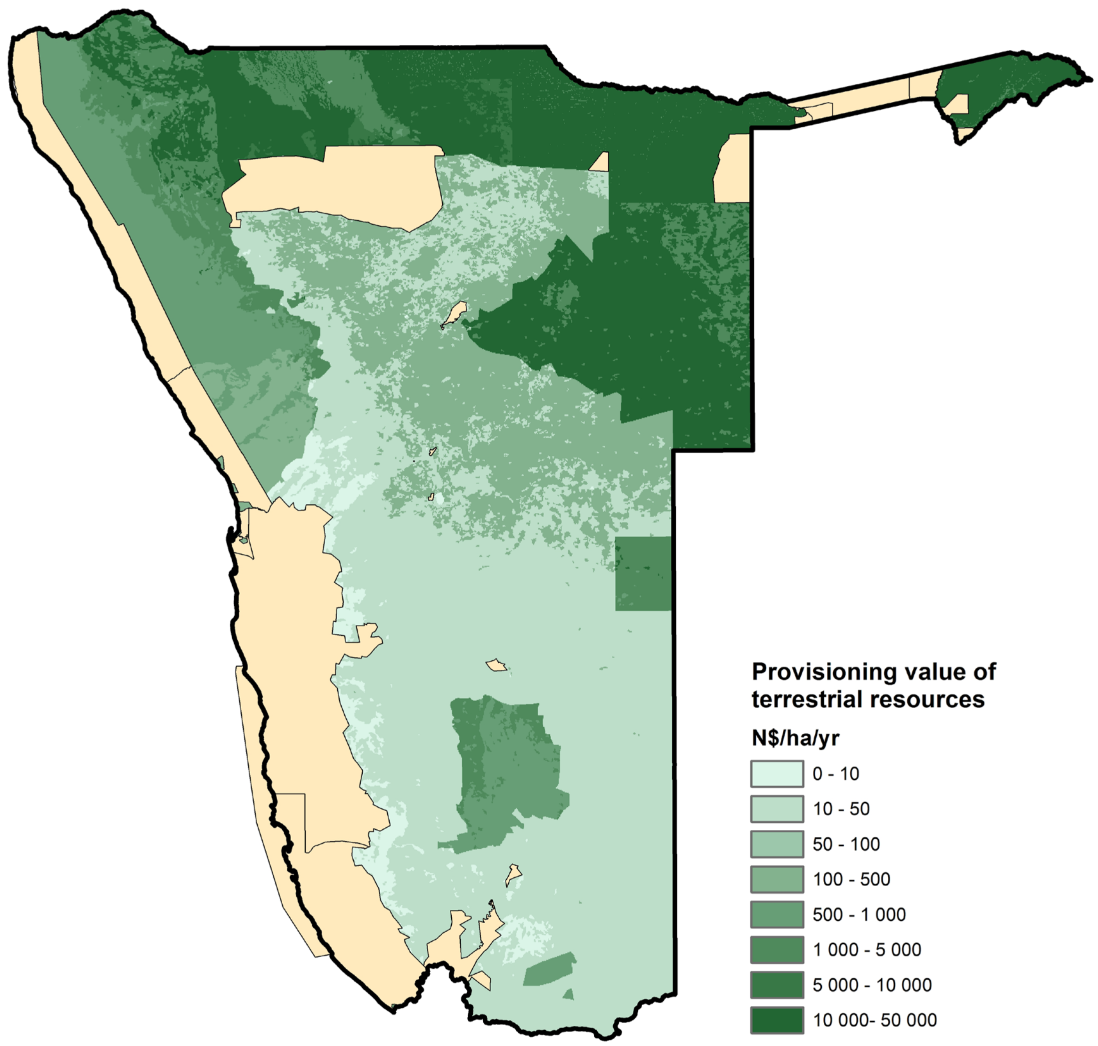
In addition, a number of indigenous plants are harvested for commercial purposes. In more recent times the commercial harvesting of wild plant species has increased, with these natural products seen as a strategy to diversify incomes and alleviate poverty in rural households. An increasing global trend towards the use of natural beauty and health care products has made the commercialisation of a number of wild plant products in Namibia possible. These include the harvesting of !nara melon, devils claw, Marula fruits and seeds, Ximenia kernels, Commiphora resin, Mopane seeds, and Sarcocaulon bark for commercial purposes to be used as ingredients in cosmetic, medicinal or food applications (Table 3.5). The current annual value of the contribution of indigenous natural products to Namibia's GDP has been estimated to be between N$35 – 59 million (Cole et al. 2014, updated to 2016 prices).

3.3.4 Summary

The total potential value of terrestrial natural resources was estimated to be in the order of N$3.3 billion per year. Taking land degradation, through bush encroachment and land clearing, into account only 90% of this value is actually realised, decreasing the value to N$3 billion per year. The decrease in this value is mainly seen in the Cuvelai drainage area where large tracts of land have been cleared for cultivation. Most of the areas affected by bush encroachment are on freehold land and therefore did not have a dramatic effect on the total value. Average value per hectare is highest

in the north-central and north-east of the country, where both biological productivity and human population densities are high (Figure 3.3).

Figure 3.3 The provisioning value (N$/ha/y) of terrestrial resources across Namibia



3.4 Inland fisheries

In Namibia inland fisheries are locally important for subsistence and employment (Sandlund & Tvedten 1992), providing livelihoods for an estimated 100 000 people (Simasiku 2014). Employment opportunities include catching, processing and trading activities. The most important inland fisheries in Namibia, both in terms of potential yield and as sources of subsistence and income, are associated with the floodplain systems of the Zambezi, Chobe, Kwando, Linyanti and Kavango rivers in the Zambezi and Kavango Regions in north-eastern Namibia (Tvedten et al. 1994). The annual flooding of these rivers is the main driving force for the breeding of fish, with the greatest survival of young fish and the overall increase in fish populations occurring in years when the water levels are high and flooding is significant (Mendelsohn & el Obeid 2004). The other freshwater ecosystems in Namibia are less productive. Nevertheless, they do represent a valuable resource for the local people in these areas.

The seasonal wetland system of the Cuvelai Drainage Area is an important source of fish for the people living in the Oshana, Omusati and Ohangwena regions. The fish stocks in the Kunene River, which forms the border between Namibia and Angola, are not exploited to any significant degree, mostly due to the low population density in this part of the country and the fact that fish are not an important food source for the Herero/Himba people (Tvedten et al. 1994). There is not much information about the utilisation of fish from the Orange River, which forms the southern border between Namibia and South Africa. Population density in this part of Namibia is also low and as a result the demand for fish is expected to be low.

Throughout the Zambezi and Kavango regions fishing is an important activity. Most households consume fish on a daily basis and the majority of households consider it the most important source of protein (Tvedten et al. 1994, Turpie et al. 1999, Mendelsohn & el Obeid 2004). The eastern Caprivi fisheries are dominated by the seasonal flooding of the Zambezi and Chobe Rivers with catches being highest during flooding (March – April) and receding of floodwaters (August to October, Turpie & Egoh 2003). The floodplains are covered by coarse perennial grasses with many meandering side streams, canals and depressions (Tvedten et al. 1994).

Further west, the Kwando River, which originates in the Angolan highlands, runs through a well-defined river valley winding through a swamp system with numerous side channels, oxbows and forested islands (Tvedten et al. 1994). The Kwando River ends by feeding into the Linyanti Swamps, but its waters may also mix with those of the Zambezi through the Linyanti Swamps, Lake Liambezi and the Chobe River (Mendelsohn et al. 2002). The Linyanti River, which flows in an easterly direction towards Lake Liambezi, is an extension of the Kwando River (Mendelsohn et al. 2002). Lake Liambezi covers an area of about 30 000 ha, of which 10 000 ha is open water when the Lake is at its fullest (Tvedten et al. 1994, Shapi 2012). It is a relatively shallow lake with a normal depth of around 3.5 metres and does not exceed depths of 6 metres at peak water levels (Simasiku 2014). The lake level is highly variable, changing with cyclical flood patterns. The lake dried out in 1985 and remained dry for 15 years, until in 2000 when it received some flood inflow (Shapi 2012). However, only in 2009 after a major flood event did the lake refill completely (Simasiku 2014). Since then the lake has received an annual inflow, which has resulted in the development of a major fishery similar to the one established on the lake during the 1970s (Shapi 2012).

The Okavango River extends 470 km in Namibia forming a significant part of the northern border with Angola. In Namibia, the Okavango forms a 2-6 km wide floodplain, encompassing an area of approximately 11 900 ha in the dry season and 43 400 ha during peak flooding (Tvedten et al. 1994). The Okavango River starts to flood in January in Namibia and reaches peak flood levels in March and April. Fishing tends to peak in September when flood waters recede and are at their lowest and fish populations are concentrated (Tvedten et al. 1994).

In the Zambezi Region, fishing effort and the percentage of households that partake in fishing activities is highest in the villages of the eastern Caprivi where the Zambezi and Chobe Rivers, Lake Liambezi and the major flooded mulapos are easily accessible. In villages in the central Caprivi fishing activities are less important with fewer households partaking. Simasiku (2014) estimated that 75% of households living in the eastern area of the Zambezi Region are physically engaged in subsistence fishing with an average reported catch of 370 kg per household per year. Turpie & Egoh (2003) estimated that fishing households in the eastern Caprivi situated around Lake Liambezi caught between 740-1740 kg per household per year. Scovronick et al. (2007) estimated the average fish for a number of villages in Kavango-Zambezi (KAZA) Transfrontier Conservation Area, ranging from 69 kg per household in the central Caprivi to 517 kg per household in the eastern Caprivi. Three surveys in the Kavango estimated that between 32 and 47% (6000-9000) of riverine households are involved in catching fish, with an estimated average consumption 10-20 kg of fish per person per year (Mendelsohn & el Obeid 2004). Van der Waal (1991) estimated that there were around 35 000 fishermen and women fishing 40 days per year along the Okavango River in Namibia.

Fish biomass in floodplain river systems is extremely variable, and as a result, estimates of fish production and sustainable yields tend to be highly uncertain (Tvedten et al. 1994, Mendelsohn & el Obeid 2004). However, a number of fishing surveys conducted over the years have estimated cropping rates and production estimates (Van der Waal 1991, Tvedten et al. 1994, Tweddle et al. 2011, Simasiku 2014). These surveys collected data on catch per unit effort, percentage fishing households, fishing time per day, fishing methods and types of fishing gear used in order to make reasonable assumptions and estimates of cropping rates and potential fish yields. Van der Waal (1990) estimated the maximum sustainable yield (MSY) for the rivers and floodplains of the Caprivi to be 1500 metric tonnes (MT) per year, including 600-700 MT from Lake Liambezi when filled.

Other earlier estimates include a potential fish production of 2250 MT per year with 100 MT for the Kwando River, 300 MT for the Linyanti River, 400 MT for the Chobe River, 300 MT for the Zambezi River, 400 MT for the eastern floodplains and 750 MT for Lake Liambezi (Tvedten et al. 1994), resulting in yield estimates of between 2.9 kg per ha for the Linyanti, 13.9 kg per ha for the Chobe, and 25 kg per ha for Lake Liambezi. More recent estimates of fish production for the Caprivi are higher than earlier estimates. Tweddle et al. (2011) estimated the fish production of Lake Liambezi to be approximately 1700 MT resulting in an annual yield of 57 kg per ha. Simasiku (2014) estimated an even higher fish production of 3193 MT on Lake Liambezi, based on data collected during intensive surveys and monitoring, resulting in an estimated annual yield of 106 kg per ha.

Tweddle & Hay (2011) estimated that all the rivers and wetlands of the Zambezi Region support an important fishery involving more than 700 fishermen and yielding 6700 MT per year. If it is assumed that between 1700 and 3000 MT of this is produced from Lake Liambezi then the other wetland systems in the eastern Caprivi would contribute between 3700 and 5000 MT per year. These estimates and averages from the more recent studies were used to determine the sustainable yields for the wetlands of the eastern Caprivi (see Table 3.6). Lake Liambezi has an estimated annual yield of 82 kg per ha in years when water levels are at their highest. The other rivers and associated floodplains are estimated to have an average annual yield of 13.4 kg per ha. This is comparable to earlier estimates by Van der Waal (1990), Tvedten et al. (1994) and from the Kafue Floodplain where 14 kg per ha was reported by Welcomme (1974).

Estimates of MSY in the Namibian section of the Okavango River vary between 840 and 3000 MT per year (Van der Waal 1991, Tvedten et al. 1994, Shapi 2012). Van der Waal (1991) estimated an annual catch of 840 MT and a yield of 19 kg per ha and Tvedten et al. (1994) estimated a catch of 1045 MT per year with an annual yield of 24 kg per ha. This provides an average annual sustainable yield of 21.7 kg per ha for the Okavango River; a reasonable estimate given the average fish biomass of 120 kg per ha estimated by Mendelsohn & el Obeid (2004). Again, as with the rivers of the eastern Caprivi, annual floods are highly variable and as a result estimating fish production and sustainable yields is difficult.

The Cuvelai system in north-central Namibia is a seasonal wetland system which is only inundated with water following rains in Angola, which occur in December to June with a maximum reached in February or March (Tvedten et al. 1994). In the Oshana Region several permanent and semi-permanent water bodies exist, known collectively as the Omadhiya Lakes. There is very little information about fishing in the Cuvelai. The quantity of fish caught annually depends on flood size and is highly variable making it difficult to accurately assess the productivity of the system. Fish is not only caught locally but a significant amount of marine fish is transported to north-central Namibia from the coast and in addition to this freshwater fish from as far afield as Angola, Okavango and Caprivi also appear in local markets (Tvedten et al. (1994)). Tvedten et al. (1994) reported that during large floods individual fishermen may catch up to 150 kg per day and it has been estimated that fish production in the Cuvelai is no less than 250 MT per year (Shapi 2012). Based on this the annual sustainable yield is estimated to be 1.3 kg per ha (Table 3.6).

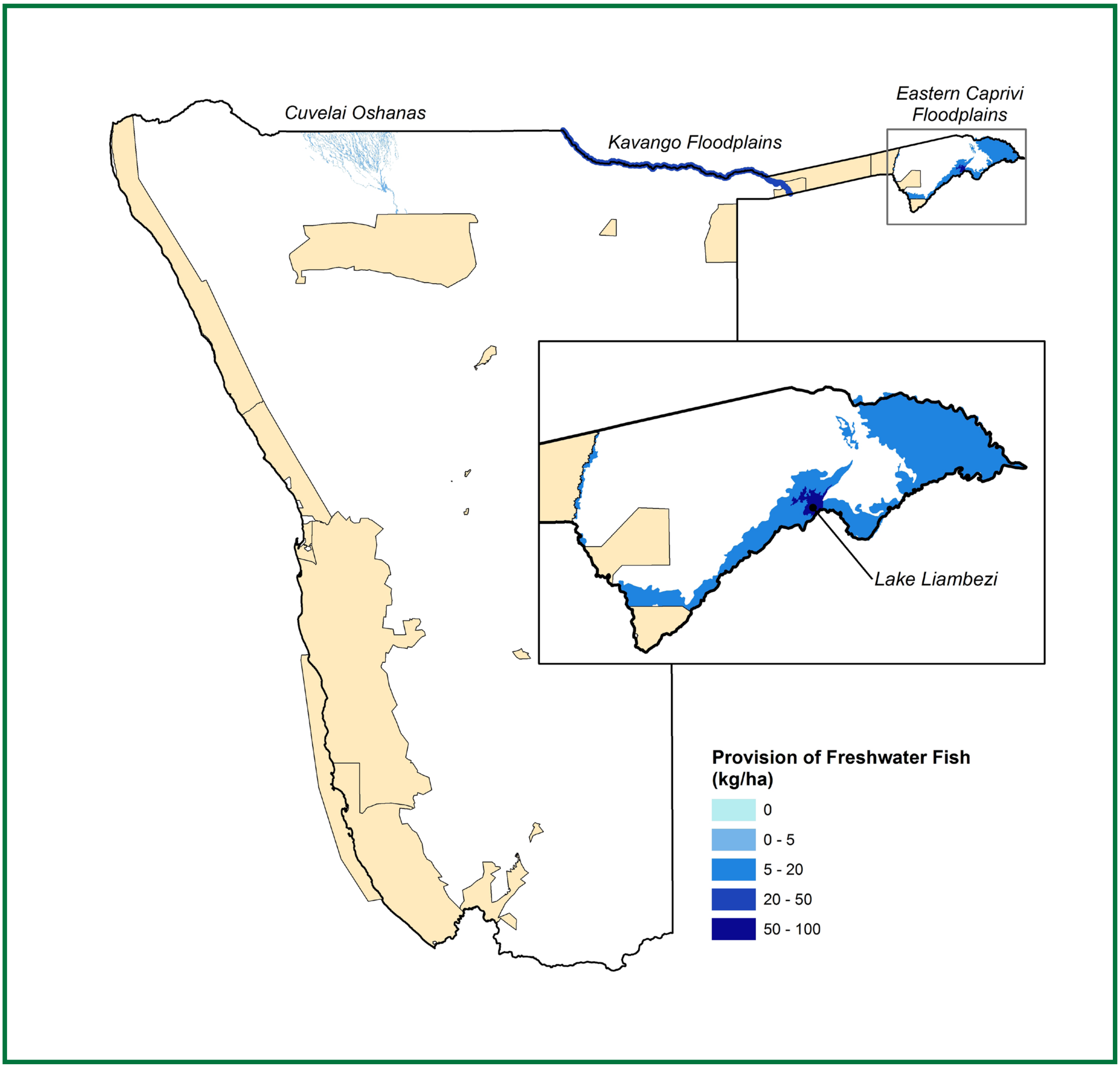
Table 3.6 Estimated sustainable fish yield (kg/ha/y) and total inland fishery value for the rivers, lake and associated floodplains in Namibia. Note: area estimates were extracted using the location of water features in Namibia as mapped in the Atlas of Namibia (Mendelsohn et al. 2003) as well as estimates from Van der Waal (1991), Tvedten et al. (1994) and Simasiku (2014)

River / floodplain / lake	Area (ha)	Sustainable yield (kg/ha	Total Value (N$ million/y)	Value per ha (N$/ha)
Zambezi River and eastern Caprivi floodplains	177 300	13.4	32.5	184
Lake Liambezi	30 000	81.6	33.5	1 118
Chobe River and swamp floodplain	28 800	13.4	5.3	184
Linyanti River and swamp floodplain	102 400	13.4	18.8	184
Kwando River and floodplain	16 400	13.4	3.0	184
Okavango River and floodplain	43 400	21.7	12.9	297
Cuvelai and Omadhiya Lakes	185 700	1.3	3.3	18
TOTAL			**109.4**	

Inland fisheries are estimated to have a value of **N$109.4 million** per year (Table 3.6). The Zambezi River and eastern Caprivi floodplains, and Lake Liambezi account for almost two thirds of this value, contributing N$32.5 and N$33.5 million per year, respectively. Lake Liambezi is the most productive system (when full) and has the highest per hectare values.

Fish biologists have noted that floodplain fish are highly adaptive which enables them to withstand considerable fishing pressure (Tvedten et al. 1994). However, increased commercialisation of the sector, modern fishing gear, and increasing population densities in combination with changes in flood regimes has led to overfishing at the community level in a number of areas in north-eastern Namibia. However, there is a strong perception about the importance of fish for livelihoods, with 63% of residents in Zambezi and 91% in Kavango believing fishing should be regulated (Tvedten et al. 1994). Due to the increase in fishing pressure a number of constructive management initiatives have been developed, such as Fish Protection Areas (FPA) on the Zambezi and Chobe Rivers as part of the integrated management of the Zambezi/Chobe River system fishery resource project, and community-based fishery management at Muyako on Lake Liambezi with the aim to protect fishery resources from over exploitation. The fisheries committee controls new entrants, collects levies from fishers and traders, and controls fishing gear regulations. Further efforts are required to increase the number of fishing villages under formal management.

Figure 3.4 Distribution of provisioning service for freshwater fish across Namibia



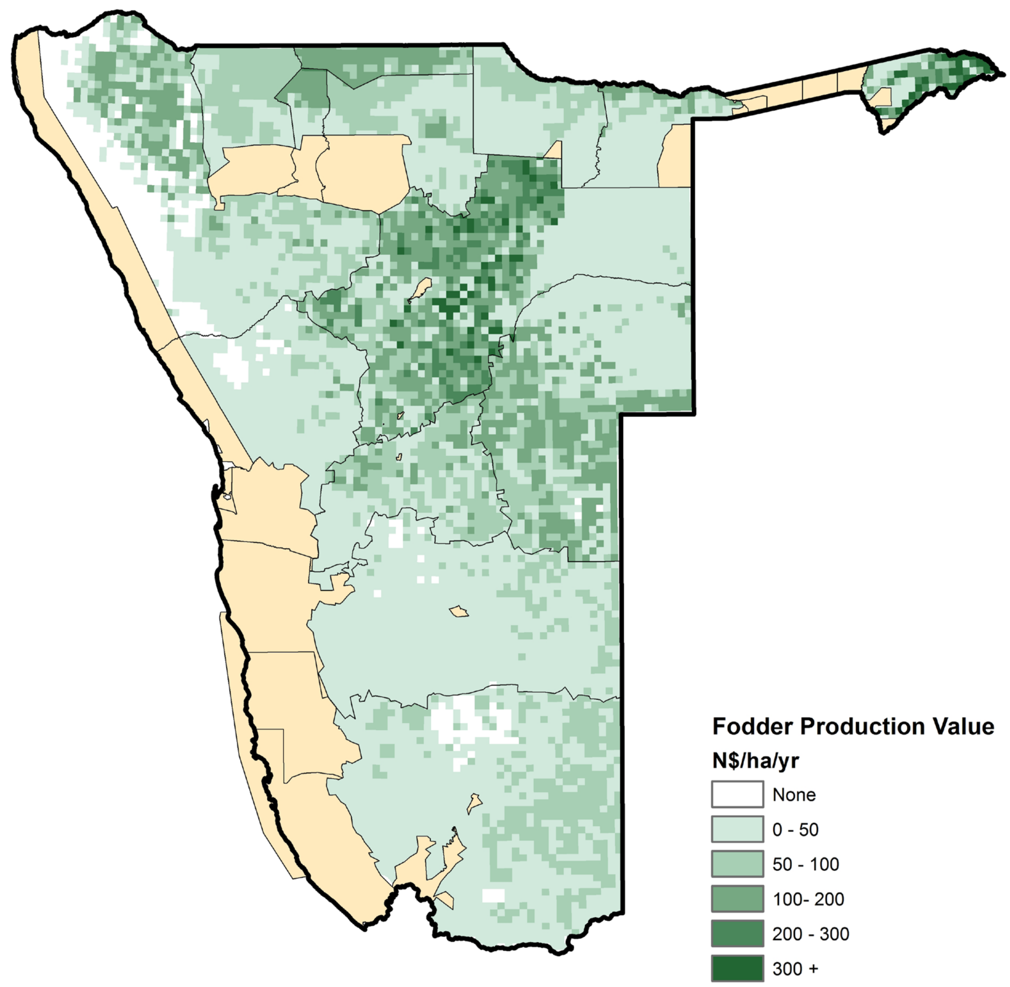
3.5 Fodder production

Much of Namibia's land area is rangeland in both communal and freehold land. In the southern sections of Namibia is mostly stocked with sheep and goats, whereas cattle are more commonly kept in northern and central areas. The carrying capacity of rangelands in Namibia ranges from very low (0-10 kg/ha) along the coast and in the far south, to over 60 kg/ha in the north-east (Mendelson et al. 2003).

The numbers of cattle, goats and sheep per region per communal and commercial farming areas were obtained from the 2002-2004 national livestock census (DVS 2006). This proportional distribution was updated to include more recent national numbers from 2015 (NSA 2017). These data indicated that there were approximately 3 million cattle kept across the country as well as almost 4 million sheep and goats.

Following from Mapiye et al. (2009), Scholtz et al. (2008, 2014), Spies (2014) and Blignaut et al. (2017) we were able to estimate the daily, and thus annual, grazing demand for cattle. This was done by multiplying the average body mass per animal per animal class (for commercial and communal herds above and below the Veterinary fence based on Lange et al. 1997, MCA 2008) with the daily fodder requirement (estimated to be 3% of body weight). The same principle was applied for sheep and goats, assuming sheep weigh 70 kg on average in commercial areas where mainly

Figure 3.5 **Distribution of fodder production value across Namibia**



dorper sheep are kept and 50 kg in communal areas where karakul goats are mainly kept. Goats were assumed to weigh 40 kg and a daily fodder demand of 3% of body mass was also applied. The total fodder demand was multiplied by the minimum commercial value of fodder which ranges between (N$2300-5000/ton in 2016).
If all livestock were subsisting entirely on wild fodder this would yield an estimated total grazing value of N$20.4 billion per year. The reality is however, that in many areas, especially highly overgrazed areas, natural forage has to be supplemented with additional feed. The 2013/2014 agricultural communal census estimated that approximately 80% of livestock only or mainly subsisted on grazing (NSA 2015). Additionally, Mendelsohn et al. (2002) mapped areas of the country considered to be overstocked and identified that the worst affected areas were north of Etosha, near Opuwo, east of the Waterberg and along the Okavango river.

The value of fodder requirement for livestock would produce an overestimate of grazing value in overstocked areas. Therefore, we estimated the difference between stocking rate and carrying capacity (Mendelsohn et al. 2002). Khomas, Zambezi and Harap regions were close to carrying capacity (within 10%), and so the full value of estimated fodder production was considered in these regions. In the other regions the fodder production value was lowered by the percentage of overstocked area until it was within 10% of carrying capacity.

The overall value of replacing fodder production in Namibia was estimated at N$18.6 billion annually. This value however, exceeds the estimated contribution of the livestock industry to GDP, which was estimated at N$2.5 billion in 2005 (MAWF 2007; equal to approximately N$3.8 billion in current prices) in Namibia. This analysis indicates that at current prices of feed, the cost of feeding cattle would outweigh any profit gained from selling the animals. The normal input costs that go into raising cattle differ depending on whether or not you live in communal or commercial farmland and the techniques you employ, however Chiriboga et al. (2008) estimated that input costs account for approximately 4-16% of production in Namibia. These inputs costs represent only a fraction of the cost required to replace fodder.

If fodder production was priced at its replacement value, realistically the industry would collapse, generating a loss of approximately **N$3.8 billion annually**. This lower value was mapped back to the regions based on the stocking density (less overstocking, Figure 3.5). Ideally the areas under wildlife use should also have been excluded (the majority of wildlife use is valued as tourism and recreation), but there are no comprehensive spatial data on this land use.

3.6 Game

Namibia supports a large game population, with approximately 90% of the country's wildlife occurring outside of formally protected areas (van Schalkwyk 2016). Up to 80% of larger game species populations occur on freehold land within Namibia (van Schalkwyk 2016).

Wild game species have a number of uses that derive value across the different land-use types in Namibia. The non-consumptive use of game occurs across most land uses in Namibia through tourism and wildlife viewing activities. The value of these non-consumptive uses is explored under the amenity value sections of this report (Section 4).

Consumptive use of wildlife occurs through hunting of game species, either for meat or trophies. Here we differentiate the use of medium and large game species from the hunting and use of smaller species (e.g. rodents, small buck) and birds for subsistence use, as the latter values have been incorporated into the wild foods and medicines portion of the provisioning value (see section 3.3.3).

Hunting of wildlife is permitted in certain areas with defined conditions. There are three main uses of game besides photographic tourism within Namibia, namely trophy hunting, hunting for meat/own-use and live sales. In addition to these legal uses, poaching of large game species occurs within certain areas on Namibia, in particular in areas neighbouring protected areas. We have not attempted to value these illegal activities as they undermine the sustainability and value of wildlife resources for other users.

Hunting of trophies is permitted on registered hunting farms. However, data on the locations of these registered farms was not available for the purposes of this mapping exercise. Trophy hunting is also permitted on communal land within conservancies with hunting partners. Currently trophy hunting is estimated to take less than 1% of the national wildlife herd each year and is considered sustainable. Hunting of specially-protected large game species such as elephant, hip-

pos and buffalo tend to occur mainly on communal land as these animals are rare on freehold land. Trophy hunting on freehold land tends to be more focused on medium-sized game species such as kudu, eland and gemsbok.

Hunting for game meat also occurs throughout Namibia, both for commercial 'shoot and sell' operations, safari hunting as well as own-use consumption. Mostly these practices occur on freehold land where landholders have rights to utilise huntable game species. However these may also occur in communal conservancies with hunting partners. The game meat for export can only originate from foot-and-mouth disease-free zones according the World Organisation for Animal Health. These areas lie south of the Veterinary Cordon Fence (VCF) which extends across north-central Namibia. Meat above the fence can only be consumed locally. Game species most commonly hunted for their meat include springbok, gemsbok, kudu, Hartmann's zebra and red hartebeest.

Live sales are another commercial use of wildlife in Namibia. Live game sales are estimated to have a value of between N$60 and N$100 million annually. The sale of live game occurs either through one of the registered game dealers in Namibia or by auction. No information is available on spatial location of farms engaging in live sales.

To estimate the potential sustainable supply of game species for both trophy and meat offtake we used population estimates for communal and freehold land and applied species specific sustainable offtakes rates. Wildlife population estimates for freehold land were based on mean densities provided by Lindsey (2011). Wildlife population estimates for communal land were taken from most recent estimates of game from national communal areas game count data (NACSO 2016). Count numbers for each conservancy that have hunting partners were averaged over the past five years (2012-2016) to get a more accurate estimate. Some neighbouring conservancies in the north-east were lumped together in terms of game populations as the animals freely move between the conservancies and so often constitute a continuous population. For conservancies where five years of estimates were not available, we used what data were available.

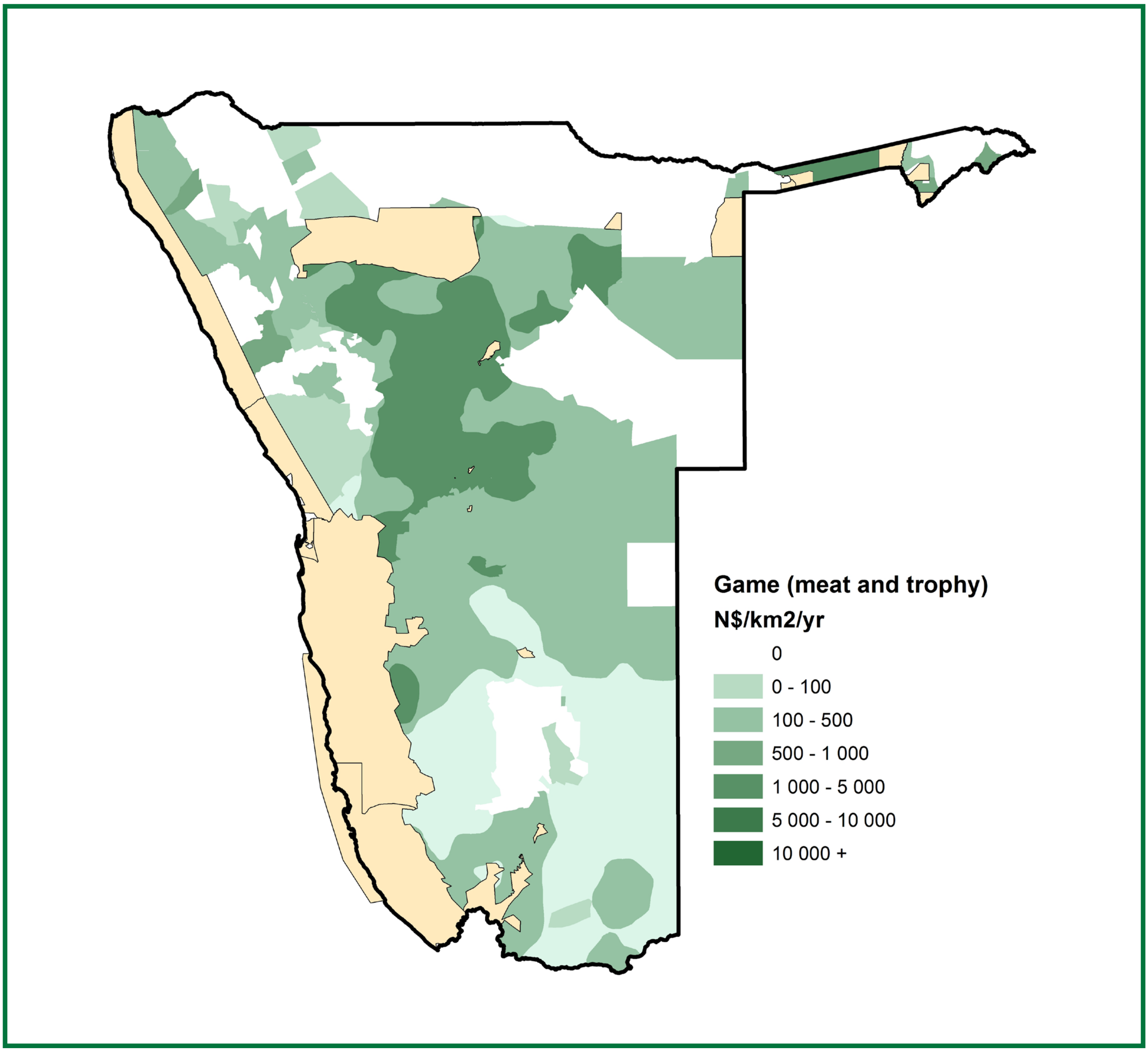
The sustainable offtake of trophy species ranged between 0-1.7% of the population depending on species (after Spinage 1987, Craig & Lawson 1990). Trophy prices for each species were based on values in Erb (2004) and updated from 2004 to current prices. Sustainable meat offtake ranged between 0-20% of the estimated population depending on the species (after Spinage 1987, Craig & Lawson 1990). To avoid double counting we assumed that the sustainable trophy yield was taken preferentially to the meat offtake. Therefore, the sustainable meat offtake was lowered to exclude the proportion taken for trophies. Meat prices of N$9.8/kg (Erb 2004) were applied to the average ratio of meat to live mass for each game species to estimate the value of meat.

The overall sustainable value of game was estimated to be about N$384 million per year for meat offtake and N$1.46 billion for trophy hunting. Not all of this value however is demanded each year. Considering the widespread nature of own-use hunting as well as biltong hunting, we assume that this portion of the value of game is fully demanded. However only approximately 25 000 permits for trophy hunting are issued each year (based on number of permits issued 2011-2014 MET data; MITSMED 2016). This may be a slight overestimate as not all permits are necessarily utilised, however actual numbers were not available. If only this proportion of the estimated sustainable offtake was realised, then the value of trophy hunting would amount to N$292 million per year.

Therefore, the gross output of game meat and trophies would amount to N$676 million per year. Barnes (2005) calculated that the resource rent value for game meat and trophies was approximately 27% of the gross output. Therefore, based on this game hunting for meat and trophies is estimated to be approximately **N$182.5 million per year**.

The mapped values (Figure 3.6) indicate the potential sustainable yield based on game count data within freehold farming areas and within communal conservancies that have hunting partners. The values are scaled based on the estimated proportion of gross output that contributes to gross national product.

Figure 3.6 Game meat and game trophy value distributed across Namibia



Picture: Gys Reitz

4

Amenity value

4 Amenity values

4.1 Introduction

The amenity value of landscapes and ecosystems is derived from their combinations of natural attributes such as size, beauty and rarity, as well as man-made enhancements such as roads, waterholes, viewpoints and other tourism infrastructure. These attributes determine the extent to which each area is suitable or attractive for recreational use, religious use or spiritual fulfilment. Their value or actual contribution to human welfare also ultimately depends on factors that influence demand for these services, such as the number and income levels of people living in the vicinity, as well as by people living elsewhere. The amenity derived from these ecosystems and landscapes can come in the form of enjoyment from tourists visiting an area, in the form for people utilising and gaining well-being from the ecosystems within the places in which they live or the as well as the enjoyment people gain by knowing that such ecosystems and landscapes exist.

Because of the intangible nature of these values, the welfare gains generated by the supply of cultural services are difficult to estimate and map (Milcu et al. 2013). In theory, the value of the cultural services provided by existing natural areas is what people would demand in compensation for giving up the benefits they receive from those areas. This can be estimated through the use of stated preference methods, involving surveys of users that elicit their willingness to pay to retain or willingness to accept compensation to forgo a certain state of the world. However, the inherent methodological biases of these methods can be extremely challenging, and require very comprehensive studies.

Nevertheless, the welfare gains associated with the amenity of ecosystems and landscapes are reflected to a large extent through the tourism market, which is tangible and observable. Visitors pay to travel to and stay in an area where they will have access to or views of different types of amenities. Thus, one can determine tourism amenity value by using revealed preference methods, in which actual data from related markets are analysed in order to estimate the contribution made by a feature of interest, in this case nature-based tourism. Another potential source of amenity value is through property value where residents pay a premium to live close to the areas they enjoy, or to have an enjoyable view. This type of value is usually realised within urban areas, where access to natural areas is limited. In this study only the tourism amenity service is mapped and valued. Some of the more intangible cultural and amenity values such as cultural significance, scientific and educational values as well as existence value are discussed below.

4.2 Tourism value

Namibia is renowned for its incredible scenic beauty, wide-open landscapes and abundant wildlife. Prior to Namibia's independence, the tourism industry was predominantly dominated by regional, self-sufficient, nature-oriented tourists (Roe et al. 2001). This led to the establishment of many campsites and rest spots catering to this kind of tourist. Since independence and the lifting of travel restrictions within Namibia's northern regions, the numbers of travellers have proliferated. The tourism industry in Namibia has seen an increase in international arrivals of 15% each year since the 1980s (Turpie et al. 2010a). The tourism industry is still centred on nature-based activities, wildlife viewing, guest farms as well as hunting tourism. In recent years, close to 1.4 million tourists arrived annually in Namibia (excluding same day visitors and returning residents; MET 2014). Leisure travel spending (both domestic and inbound) generated

approximately 80.3% of direct travel and tourism GDP in 2014, compared with 19.7% for business travel spending (WTTC 2015). Turpie et al. (2010a) estimated that 70% of the total tourism expenditure in Namibia can be attributed to nature-based tourism.

In 2014 the direct contribution of travel and tourism to Namibian GDP was N$3.77 billion, or 3% of total GDP (WTTC 2015). The total contribution of travel and tourism in 2014, which includes indirect and induced impacts, was estimated to be N$18.4 billion, or 14.9% of total GDP (WTTC 2015). This makes tourism one of the main contributors to GDP within Namibia alongside mining, fisheries and agriculture (Namibia Tourism 2000).

Determining the tourism value of particular areas often involves on-site collection of data from tourists visiting these areas. Techniques such as travel cost analysis or revealed preferences can be used to determine the consumers' surplus or the net welfare gain resulting from visiting these parks (Willis & Benson 1989, Shrestha et al. 2007, Wood et al. 2013). While these kinds of methods may be useful for small defined areas such as parks, they are impractical for estimation of the value of multiple sites across an extensive area. Most efforts to quantify and map cultural services such as recreational value have used the number of visitors to an area as a proxy (Hill & Courtney 2006). Other proxies include number of tourist attractions, tourist expenditure, sightings of rare species, accessibility to natural areas and days spent fishing (Raudsepp-Hearne et al. 2010; Chan et al. 2011; O'Farrell et al. 2011).

The recent emergence of various social media tools, however, provides an alternative to assess how people respond to nature and open space areas (Wood et al. 2013). One such way of doing this is to analyse the pattern of georeferenced photographs taken by the public and uploaded onto the Internet. Geo-tagged imagery can provide information about the places depicted in the photographs, as well as the interests, behaviours and mobility of the people who took the photographs (Andrienko et al. 2009).

With the increasing number of people utilising the internet worldwide, several researchers have begun to use social media data for mapping of recreational ecosystem services, and to determine the appeal of a particular natural asset to both tourists and locals (Alfaro 2015, Kachkaev & Wood 2013, Howarth 2012). An advantage of this approach is that data are often free and quicker to access than by traditional means (e.g. surveys). Furthermore, it holds "big data" (Goes 2014), because an enormous amount of information is submitted by millions of users worldwide. This "big data" is available through virtual sources which can be utilised by academics, consultants and organisations that are looking to evaluate people's preference for certain natural commodities (Alfaro 2015). For instance, thirteen billion images have been uploaded onto Flickr by Yahoo, to its public database alone. Social media websites such as Flickr and Panoramio (by Google) can therefore provide a wealth of information through their numerous geo-tagged photographs for example location, distribution and types of interests, in addition to users' demographics (Wood et al. 2013).

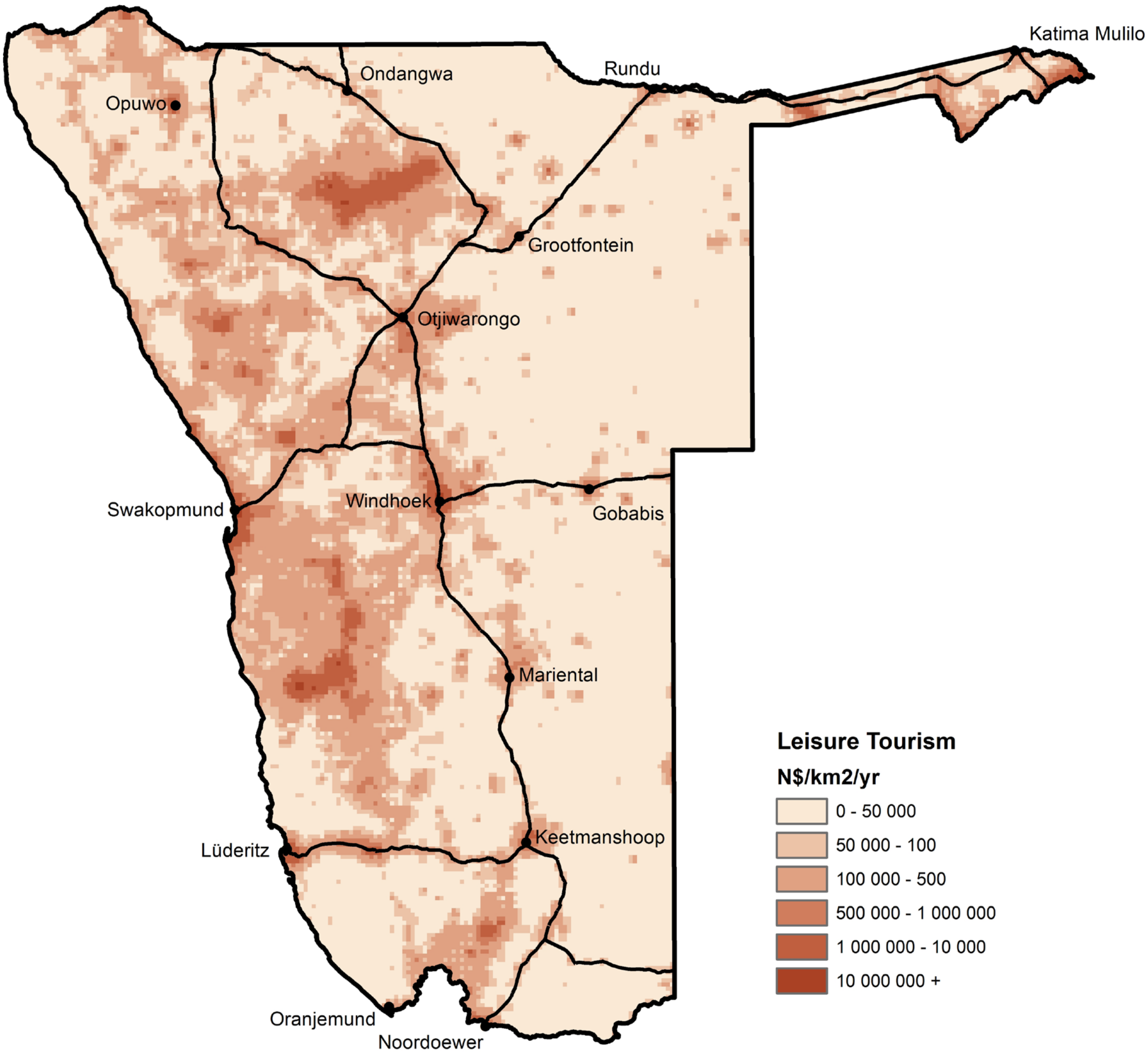
The use of the geo-tagged photo data method is based on the premise that the numbers of photographs uploaded to these sites are correlated with the recreational value of different areas (Casalegno et al. 2013). Several studies have used this method both within Africa and internationally. Turpie & Marx (2012) used photographs from Panoramio.com to estimate landscape contribution to tourism value in the Erongo region of Namibia and Turpie et al. (2014) used a kriging method to analyse patterns of Panoramio photo uploads to map tourism value across Zambia. Li et al. (2011) used parameters recorded by tourists' digital cameras and stored in Panoramio to determine tourists' temporal variations, length of stay, daily average number of tourists, individual movement traces and a flow map. Casalegno et al. (2013) used the number of individuals (expressed per 1 km2) who uploaded photographs onto Google Earth (via Panoramio) as a measure of recreation rather than the total number of photographs. Alfaro (2015) used photographs taken from Panoramio and Flickr to estimate the distribution of recreational services in Nebraska. By determining the location of clusters of photographs and comparing these clusters to population density, the researcher was able to identify new areas of high recreational value.

In this study, the spatial distribution of tourism value was mapped using InVEST Recreation Model 3.2.2 (www.naturalcapitalproject.org). This model uses geotagged photographs uploaded on the website Flickr in order to estimate the relative value of tourism/recreation across an area. The model then calculated the average annual photo-user-days (PUDs) for each grid cell across the period 2005-2014. The model used the latitude/longitude data from photographs as well as the photographer's user-name and photo date to calculate PUDs. One PUD is one unique photographer who took at least one photo in a specific location on a single day. This minimises the duplicated counts due to one photographer taking multiple photos at any given site.

Across Namibia an annual average of 2810 PUDs were recorded, with the highest proportion of PUDs being recorded in August and September. The distribution of photos correlated well with major tourism routes, with concentrations around major towns such as Windhoek, Swakopmund and Otjiwarongo, as well as tourism destinations such as Etosha National Park, The Namib-Naukluft Park near Sesriem as well as within Damaraland (Figure 4.1). With exception of the Caprivi, the Eastern Areas of Namibia show relatively lower tourism value.

In order to map a value to the distribution of PUDs, the leisure tourism value from WTTC (2014) was used (N$13 billion, WTTC 2014). This value represents both the domestic and international spending on non-business related travel in Namibia. Not all of this value can be directly attributable to nature as spending also takes place in urban centres in the form of shopping, cultural, medical and other non-nature related activities. However, inspection of the distribution of the value in Figure 4.1 suggests that while there are concentrations around urban centres, the majority of pictures outside urban areas are along main nature-based tourism routes. Data from tourist surveys (e.g. MET 2013, 2014 & 2016) can reveal the relative importance of different kinds of activities to tourists. While cultural tourism does make up a small percentage of the tourism to these rural areas, cultural activities were reported by 1% of domestic and less

Figure 4.1 Distribution of tourism value across Namibia as a function of the number of Photo User Days as calculated by the InVEST Recreation model (Natural Capital Project 2017



than 5% of international tourists (MET 2013 & 2016). Approximately 85% of the photos were outside of main urban centres and therefore are assumed to contain natural landscapes and/or features.

Not only holiday tourists draw value from Namibia's natural ecosystems. Many tourists visiting for other reasons may also visit natural areas even though this was not the primary function of their trip. It is important however, to separate out how much each group spend on natural attractions, as it varies widely between other groups of non-holiday tourists. For example, Namibia enjoys a large number of tourists entering each year from neighbouring Angola. Many of these using data from MET (2013, 2014 & 2016) we estimated the relative spend of the main groups of visitors namely holiday, visiting family and relatives (VFR), business and other. The estimates of spending of leisure and business spending were then distributed into these categories accordingly (Table 4.1). We used data on the main activities undertaken by visitors to estimate what percentage of visitors took part in nature-based activities. These values different between different groups, with the highest percentages found in holiday tourists (74% international and 23% domestic) followed by those visiting family and relatives (32% international and 4% domestic). The only data available to estimate the proportion of the total was in the form of a list of activities undertaken by tourists (MET 2013 & 2016). While this does give an indication of the relative importance of different activities, the surveys were not designed to specifically estimate the % of nature-based tourism spending. The estimates derived using this data are likely an underestimate of total nature-based tourism spending. Tourists travelling overseas to Namibia, even if they undertake some non-nature-based activities whilst here, often choose to visit the country based on its combination of natural features (landscapes and wildlife).

Table 4.1 **Percentage break down of international (Int.) and domestic (Dom.) visitors within Namibia as well as their relative spending (WTTC 2014, MET 2013, 2014, 2016). The estimated amount of this value that is estimated to be nature-based is also summarised**

Category	% of Int. visitorS	% of Dom. tourists	Estimated spend Int. (N$m)	Estimated spend Dom. (N$m)	Nature-based spend Int. (N$m)	Nature-based Dom. (N$)
VFR	48%	43%	2 994	1 198	958	48
Holiday	39%	23%	5 315	1 546	3 933	356
Other	7%	23%	1 535	593	123	6
Business	13%	11%	2 418	820	387	57
Total			**12 263**	**4 157**	**5 401**	**467**

The total tourism spend (leisure and business) across Namibia is estimated to be N$16.4 billion per annum (WTTC 2014). Using the best available data, we estimate that at least **N$5.2 billion** of this value (36%) is directly attributable to the natural environment. This figure however is likely an underestimate. While 85% of this spending falls under leisure spending, an additional N$444 million is estimated to come from tourists whose main purpose of travel was for business.

4.3 Non-market values

Some of the more intangible cultural and amenity values such as scientific and educational values as well as existence value and cultural significance are difficult or impossible to fully value in monetary terms. The value that these services provide are important and should be recognised.

Natural ecosystems provide a number of opportunities for education, study and research, as well as provide references for monitoring environmental change. Nature provides opportunities for cognitive development and is used for developing interest and knowledge from a young age through, for example, school excursions (UK NEA 2011). The benefits of scientific and educational functions provided by the environment include access to genetic resources, new medicines, experimental conditions for scientific research and study materials for education. Attempts to value this service can include quantifying income from nature-based educational centres, the value of scientific discoveries being produced by a countries' biodiversity or investments in ecological and environmental research (Chiesura & de Groot 2003). These

expenditures however are likely to be small in relation to the long-term value of scientific and educational value to Namibia's ecosystems.

Namibia's unique and stark landscapes have widespread appeal, especially in photographs and film. Namibia's wide open vistas and red dunes are distinctive and feature in many photographic and landscape books. Namibia, especially its desert, has also been the setting of many feature films, documentaries and TV series (Namibian Film Commission 2017). These values are relatively intangible, but may be valued through investment in research, and the market value of books and films relating to the environment (Chiesura & de Groot 2003). While not valued here, the value of Namibia's environmental to these industries is not insignificant.

In addition to the nature tourism and wildlife volunteer tourism that exist within Namibia, there are also many wildlife and conservation NGO's which receive donations from overseas people, many of which may never actually visit Namibia, but for who the knowledge that they are contributing to the conservation of these animals and landscapes brings immense pleasure. Namibia is home to many different species of charismatic megafauna that attract much attention through media and consequently donor funding. While the total sum of these donations can give an indication of the willingness to pay for the existence of Namibia's nature, it does not capture the entire value. The direct income from fundraising for conservation-related projects was estimated at N$54 million in 2003-4 (Turpie et al. 2010a), which has likely increased substantially since this time as Namibia has become a more popular tourist destination and knowledge of Namibia as a country has increased. Even if the number of NGO's were the same (which is unlikely), this value would equate to over N$90 million in current prices.

Spirituality can relate to religious values that are held by local indigenous communities or it can relate to the values of those who find spiritual inspiration from nature (UK NEA 2011). Spiritual inspiration can be described as the enrichment, experience, solace, enlightenment, fulfilment, or reflection that individuals take from nature (UK NEA 2011, Daniel et al. 2012). While the cultural and spiritual value of nature is often viewed separately from other services like provisioning services, in many cases they can actually be intertwined and co-occurring. Schnegg et al. (2014) conducted participatory mapping of where people derived ecosystem services in a village in northern Namibia.

Cultural services included non-material services like beauty, health, learning, sense of belonging and spirituality and religion as well as material services such as resources and food. They found that many of these 'cultural services' actually overlapped with other types of services like fishing or collecting other resources rather than being obtained on their own. This is in contrast to other forms of amenity value such as tourism value which is generally a singular pursuit. This co-occurrence of ecosystem services derived by natural for rural land users is not uncommon. Xhosa women and men in South Africa report that harvesting resources or hunting in the forest also provide them with value through spiritual connection and increased mental well-being (Cocks et al. 2013).

Collection of many of the natural resources described in Section 3 could potentially have cultural significance or values that go above and beyond the benefit derived from the materials gathered themselves. Given Namibia's rich and complex cultural heritage it is also likely that these values are different between different parts of the country and between different ethnic groups. These values as well as the existence values associated with the appreciation of Namibia's flora and fauna and their continuance are only measurable using stated preference techniques. These techniques inadequately capture the true value as they are very dependent on the income levels of the participants, which are hugely disparate when taking into account the value to local Namibian's as well as foreigners from developed countries. The value of these services is however critical to the well-being of a large number of people.

5

Regulating services


Picture: Ralf Bäcker

5 Regulating services

5.1 Agricultural Support

Natural environments can contribute to agricultural production through pollination and pest control. A majority of commercial crops are dependent upon honeybee pollination in order to produce fruit and seed, and as much as 30% of worldwide food production is reliant upon this service (de Groot 2002, Kremen et al. 2002). Most of the agricultural land in Namibia is dedicated to livestock farming, however, some large tracts of land have been cleared for cultivation. The largest areas of cultivated land are found in the northern communal areas. The main crops grown within these areas are dryland cultivation of crops cereal crops such as mahangu (pearl millet), maize and wheat. These crops are all wind pollinated and therefore do not benefit from any pollination service provided by wild insects.

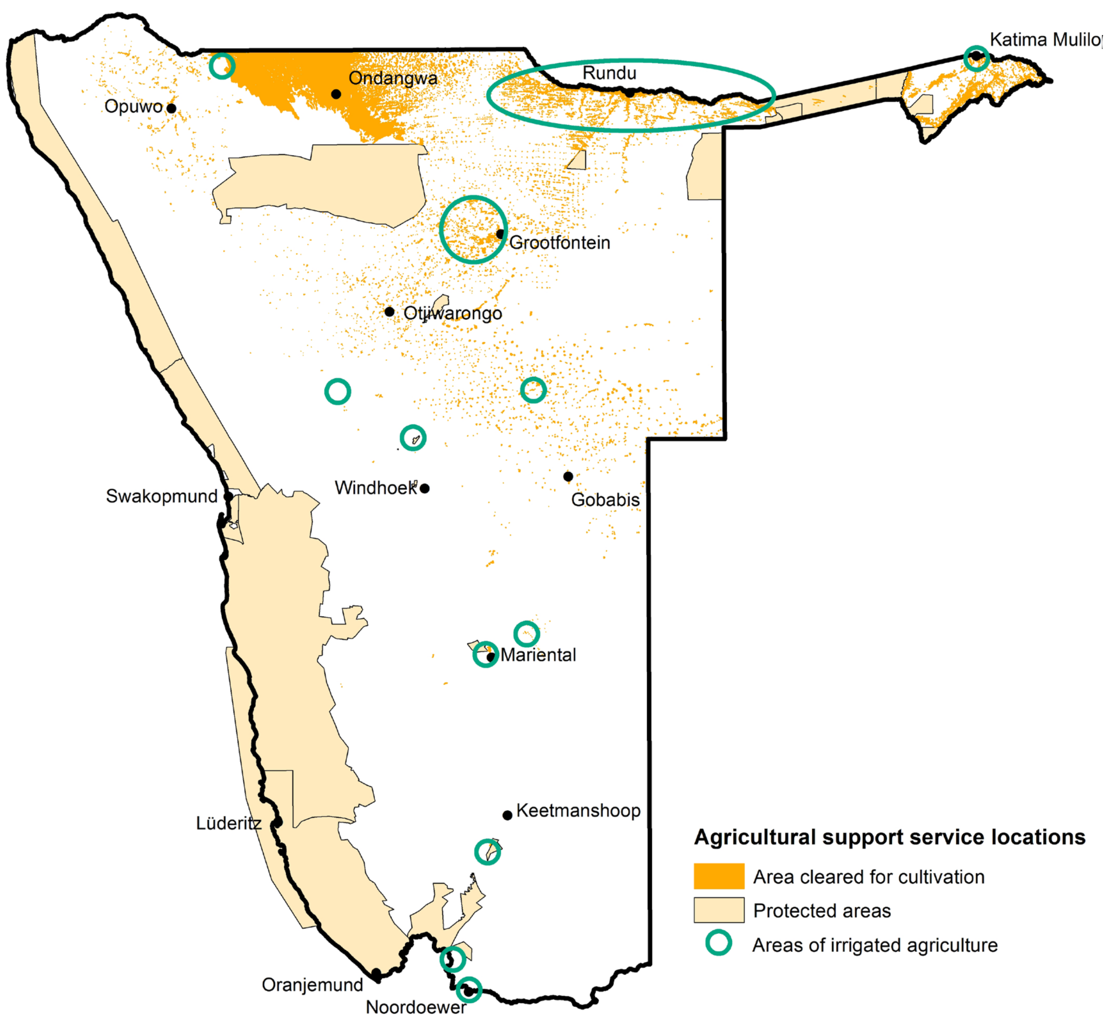
While approximately 43 500 ha of land in Namibia holds potential for irrigated agriculture, only 7 700 ha were under irrigation in 2005 (PWC 2004). There has been a push from the government through its Green Scheme Policy to encourage the expansions of the irrigated field crop sector in order to try and achieve both national social development goals as well as food self-sufficiency (Haidula 2016). The Green Scheme aims to develop 27 000 ha for irrigation over a 15 year period (Botes 2005). A large proportion of this irrigated area is under cereal and fodder crops and only approximately a third consists of higher value crops such as vegetables and fruits (FAO 2017). However, the production of horticultural fresh produce has increased dramatically in the last decade with a reported growth of demand of 15-25% annually (Fiebiger et al. 2010).

Currently there are a number of concentrations of irrigated agriculture in Namibia mainly along rivers, below dams or using artisanal water sources (Figure 5.1). In the north of Namibia the main areas of irrigated agriculture include those near Ruacana, along the Okavango River near Rundu as well as along the Zambezi near Katima Mulilo. There are also small irrigation schemes situated along the Orange, Swakop and Omaruru rivers. Using artisanal water sources, irrigated agriculture occurs in the ‘maize triangle’ between the towns of Otavi, Grootfontein and Tsumeb (Oshikoto Region) as well as smaller towns such as Stampriet in (Hardap Region) and Hochfeld (Otjozondupa Region). Irrigation schemes also exist adjacent to the Hardap Dam (Hardap Region) and the Naute Dam (Karas Region).

The non-cereal and fodder crops grown in irrigated agricultural schemes are comprised mainly of leafy green vegetables in northern regions and grapes and dates in the southern regions. Other main crops include potatoes, onions and tomatoes. The proportions of crops that may rely on wild pollinators make up a small fraction of an already small industry. Namibia is a net importer of fruits and vegetables from South Africa, where rain fed, year-round production is more possible. Statistics from 2012/2013 (Namibian Agronomic Board 2017) indicate that just less than half of fresh produce was produced locally within Namibia, totalling a value of approximately N$80 million. Of this, less than N$20 million was from crops that benefit from insect pollination (tomatoes, cucumber, peppers and melons).

Subsistence crops, which mainly occur in the northern communal areas are also largely dominated by cereal crops. Households often also have small vegetable gardens, however these are often seasonal and produce a limited variety of vegetables and fruits. Vegetables grown in gardens are either consumed within households with excess sold at in-

Figure 5.1 Area cleared for cultivation and the main areas of irrigation across Namibia



formal markets. The areas with the highest concentration of vegetable growers occur in towns along main roads such as in the Kavango region where up to 40% of households along the Grootfontein-Rundu road grow vegetables and 15% sell them (Ministry of Agriculture, Water and Rural Development 2001) while only 1% of the households in the region reported partaking in horticulture exclusively (El Obeid & Mendelsohn 2001).

There is some small-scale bee keeping (for honey) occurring throughout Namibia, however there are no commercial businesses offering pollination services to farmers to increase production. The majority of pollination is likely occurring through either hand or wild insect pollination. Despite no spatial data on the distribution of crop types throughout Namibia, the value of wild pollination services would likely be attributable to the natural vegetation surrounding irrigated areas indicated in Figure 5.1. There would also be a smaller value attributable to natural vegetation surrounding subsistence vegetable gardens.

In addition to pollination, animals residing in natural habitats provide some degree of control of agricultural pests through predation (Cardinale et al. 2003; Cullen et al. 2008, Griffiths et al. 2008), although estimates of this service are rare (Jonsson et al. 2008). If these natural habitats are lost this service would no longer be supplied and it is expected that pest damage would increase, leading to lower production and increase expenditure on control methods.

Losey & Vaughan (2006) estimated that pest control saves 4.24% of total crop production value in the USA. Using this

figure and extrapolating to the value of production of crops in Namibia suggests that pest control services could be worth some N$37 million in Namibia (based on production and price of white maize, mahungu (pearl millet), wheat and horticulture, Namibian Agronomic Board 2017). Based on studies of insect dispersal in this regard (Byrne 1999, Zehnder et al. 2007, Bianchi et al. 2008, Tscharntke et al. 2007), this value would be mostly attributed to natural habitats within about 2 km of agricultural fields.

5.2 Flood attenuation

Flooding is influenced by a combination of weather related factors (e.g. rainfall intensity extent and duration) as well as geophysical characteristics of the catchment including size, steepness, soil and land uses (Kareiva et al. 2011). Natural systems such as wetlands and rivers or ecosystems with deep permeable soils can regulate flows through the landscape by slowing flows by means of storage and vegetative resistance as well as facilitating infiltration into soils. Vegetation across the terrestrial landscape can also help slow overland flows and increase infiltration before the water reaches rivers and streams. In this way these systems ameliorate the potential impacts of flood events by reducing the flood peaks and lengthening the flood period at a lower level, reducing bank and streambed erosion (Vellidis et al. 2003), as well as reducing the risk of damage caused by flooding of downstream areas.

Within Namibia, the majority of rain that falls is lost to evaporation, with only a very small amount contributing to surface run-off (Heyns et al. 1998). Namibia's surface water consists of mainly ephemeral rivers that only flow during heavy rainfall, and often not along their entire reach. The only perennial river systems are those along Namibia's borders, namely the Orange in the south, Kunene in the north-west, Okavango, the Kwando-Chobe-Linyanti system and Zambezi systems in the north-east (Figure 5.2). These rivers are fed from rainfall in catchments that lie outside of Namibia's borders. Wetlands in Namibia are mainly confined to the floodplains of the few perennial rivers, as well as the complex of ephemeral pans and depressions in the Cuvelai system north of Etosha (Figure 5.2 on the next page). These wetland systems tend to also be where major flooding events that cause damage occur within Namibia.

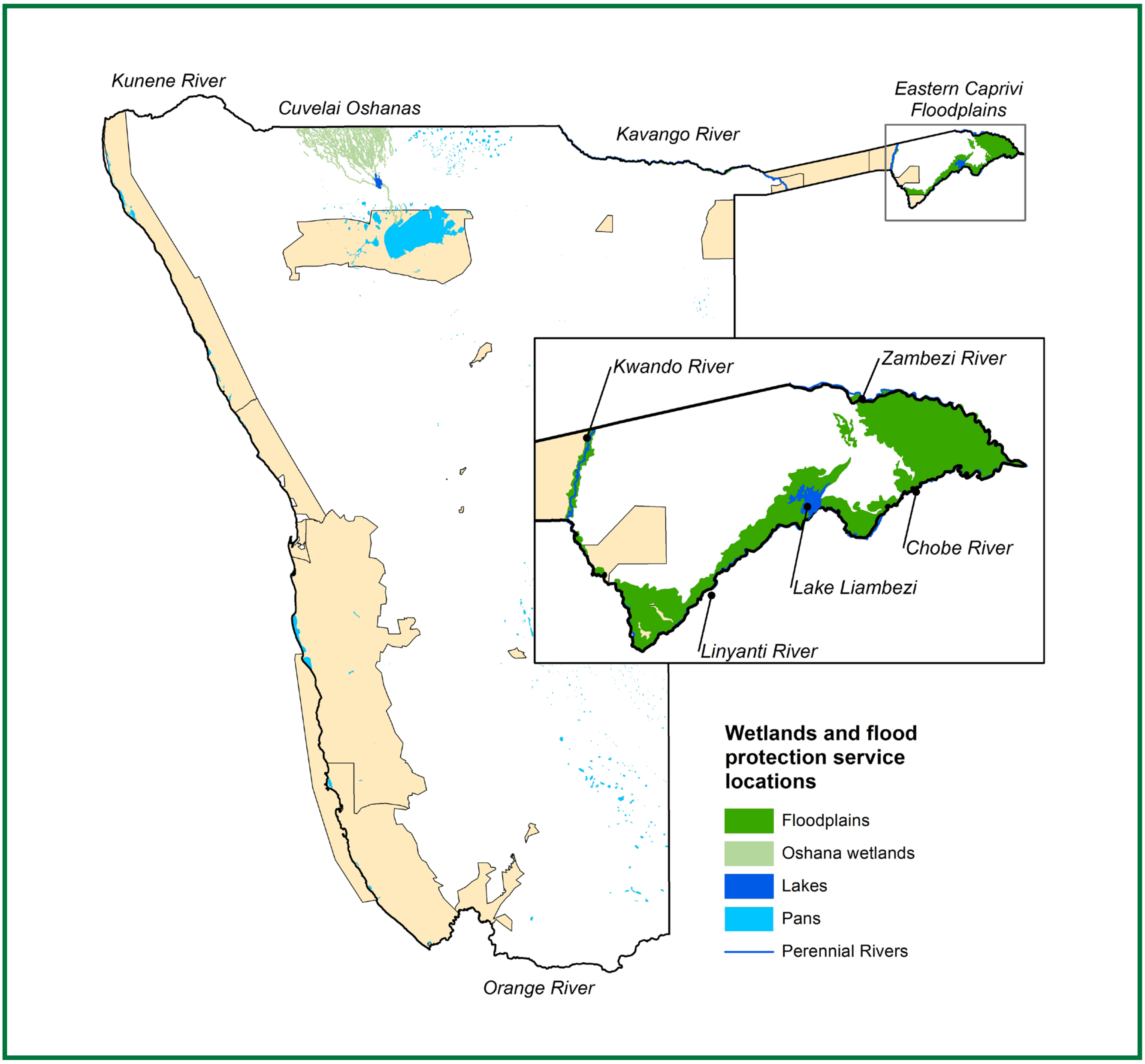
5.2.1 Cuvelai Wetlands

The area in which flooding is most commonly an issue is in the Cuvelai system spanning the Omusati and Oshana regions in northern Namibia. Here, however the relationship between people and flooding is complex. This area consists of a number of interconnected channels and depressions called 'Oshanas'. These areas fill seasonally with water and floodwaters bring new sediment making the area quite productive. These annual floods often bring essential water and life into these systems that help sustain the large number of agricultural households (Tuwilika 2016). In an otherwise very arid country, the Cuvelai drainage area has attracted habitation because of this availability of water and is able to support much higher population densities than many other areas within the country. However, above-average flooding can also damage property as well as lead to loss of life, crops and livestock (Tuwilika 2016). Within the Culvelai area crops are grown set distances away from waterbodies in order to allow them accesses to the water table, but without becoming waterlogged. Increasing population pressure in these areas means that the safer higher-lying areas are less available and people are forced to conduct their livelihoods in lower-lying areas more prone to being damaged in large-flood events (Tuwilika 2016).

Increasing population has also lead to an increase in grazing pressure on the surrounding grasslands, often leading to overgrazing, loss of ground cover and erosion in many areas (Strohbach 2000). Based on erosion hazard index, rainfall index, livestock pressure index and population pressure index the Oshana region is rated as having some of the highest land degradation risk in Namibia (Klintenberg & Seely 2005). When these areas become degraded, they are more prone to sediment loss through erosion, which in turn can potentially silt-up depressions and pans, decreasing their storage potential. This decreased storage causes a loss of flow regulating ability during flooding events, which could in turn exacerbate flooding, especially further downstream.

In many flood-prone areas, the downstream area of the catchment is where the worst flooding and damage is seen. In contrast, in the Cuvelai basin, lower down in the catchment floods are seen as more beneficial and less detrimental than further north. This is because these areas receive less rainfall and so floods are associated with greater grazing production (Tuwilika 2016). Were the Oshanas further north not present the flooding would likely be much more severe. But conversely, were they in better condition (i.e. not as silted up), there would likely be less flooding (and therefore access to water) further south.

Figure 5.2 Distribution of wetlands and perennial rivers across Namibia



Through degradation, the Cuvelai has lost some if its flood regulating ability not only because of loss of storage in wetlands, but also through loss of vegetation which can slow overland and instream flows. Further modelling would be required to investigate the value of this service.

5.2.2 Perennial river floodplains

The Kwando-Linyanti-Chobe-Zambezi system in the Caprivi has complicated hydrology. As with many rivers in Southern Africa, flow is seasonal and can vary greatly between successive years, including sections drying up completely for many years. The Kwando River originates in Angola and flows south through the neck of the Caprivi. Along its length through Namibia, the Kwando is lined with 1-2 km of floodplain wetlands (Kurugundla et al. 2010). The river then turns south-east, becoming the Linyanti River and forms the border between Namibia and Botswana with 5-10 km of floodplain wetlands (Kurugundla et al. 2010). The river, when flowing along entire length terminates in the Lake Liambezi (Kurugundla et al. 2010). South-east of the lake is the Chobe River and floodplains which connect to the Zambezi. These wetlands can either flow east, when Lake Zambezi is full via the Savuti channel, or can back up from the Zambezi and flow in opposite direction (Burke 2015).

The Zambezi flows southeast along the northern-eastern border of the Caprivi. During large flood events, extensive wetlands covering thousands of square kilometres can become inundated. These wetlands in the eastern Caprivi play an important role in regulating flood waters along the Zambezi River. During flood events, these wetlands flood and reduce the flood peak experienced further downstream at Victoria Falls (Murwira et al. 2004). These eastern Caprivi wetlands can hold upwards of 20 billion m^3 of water spread over 2500 km2 (Murwira et al. 2004).

By comparison, wetland systems along the other perennial rivers in Namibia are much smaller. The Kavango River has less than 2 km of floodplain along its entire reach within Namibia which are dwarfed in comparison by the extensive Okavango floodplains further along the river in Botswana. The Kunene River has very few wetlands along its reach and its flow is now mainly controlled via a series of dams in Angola above the Ruacana Falls. The Orange River also does not have extensive floodplain wetlands as most attenuation of the rivers flows happens in the upper catchments which are within South Africa and Lesotho.

5.2.3 Ephemeral rivers

Namibia's ephemeral rivers generally occur in the drier, less populated areas of the country and consequently there is little infrastructure other than roads and bridges that could potentially be damaged by floods. These rivers flow only under high rainfall events and may not flow every year. On rivers that do flow more frequently, dams have been built to capture flood waters for use throughout the year, these also help regulate flows, preventing downstream flooding.

In these systems, there are no permanent wetlands that have water storage capacity, however any vegetation along the banks and in the river bed may have some effect on slowing flows during flood events. Many ephemeral river courses in Namibia are invaded by alien Propsopis spp (NNF 2016). These plants may actually slow floods and offer greater flood attenuation ability than natural vegetation (scattered camelthorn, Acacia erioloba, trees). However, they also interfere with the natural flood regime of the system, upon which these ecosystems depend, and reduce the groundwater recharge occurring along rivers.

5.2.4 Valuing the service

An approach to estimate the flood retention value of Namibia's wetlands would involve estimating the cost of replacing the service or the value of the damages avoided. In order to estimate the replacement cost it would be important to determine the demand for these services by establishing whether infrastructure exists within downstream flood risk areas. Without these data it is hard to estimate the value of this service. Using the assumption that the service provided for the Zambezi wetlands is fully demanded, and the annualised cost per m^3 of building a dam the value could be in the order of N$50 billion per year. However, it is unlikely this service is fully demanded, and additionally the benefits are felt by countries downstream rather than Namibia itself.

The steps involved in conducting a thorough analysis would include 1) estimating the holding capacity of the different wetlands systems, or slowing effect of vegetation, 2) estimating the change in flood extent downstream using hydrological models, 3) identifying which systems have infrastructure downstream that would demand the flood retention service and finally 4) estimating the cost of replacing the service where demanded within Namibia.

5.3 Control of erosion and sedimentation

Human activities across the landscape often lead to changes in the amounts of sediments entering aquatic ecosystems. Landscape degradation is one of the leading causes of increased sediment inputs, mainly through decreases in vegetation cover and erosion of soil through over grazing.

Erosion and sedimentation are natural processes that play an important role in delivering nutrients to floodplains, estuaries and marine environments. In Namibia's ephemeral river systems, rainfall often occurs at the end of the dry season, when vegetation cover is at its lowest. Rainfall occurring later in the wet season will cause less erosion once grass cover has increased. As a result, flash floods with high sediment loads are not uncommon. When land degradation occurs, this natural process becomes exacerbated and can lead to the loss of important topsoil as well the delivery of excess sediments into waterways.

The extent to which sediments end up in river systems is determined by a number of factors including the soil type, rainfall patterns (amount and intensity), slope and the type and amount of vegetative cover. Vegetative cover prevents erosion by stabilizing soil and by intercepting rainfall, thereby reducing its erosivity (De Groot et al. 2002). This is particularly valuable where soils are highly erodible. Vegetated areas, especially wetlands, may also capture the sediments that are eroded from agricultural and degraded lands and transported in surface flows, preventing them from entering streams and rivers (Blumenfeld et al. 2009, Conte et al. 2011). Sediment deposition in wetlands depends upon a number of factors including water velocity, flooding regimes, vegetated area of the wetland, and water retention time (Gilliam 1994; Johnston 1991). Sediment deposition in wetlands prevents a source of turbidity from entering downstream ecosystems and prevents siltation of rivers downstream. Typically wetland vegetation can trap up to 80-90% of sediment coming from the runoff of the catchment (Gilliam 1994; Johnston 1991). This protects downstream areas from the impacts of sedimentation, which can include impacts on water storage capacity, hydropower generation and navigability of rivers (Pimentel et al. 1995).

Within Namibia, erosion has not been recognised as a severe problem, especially in the face of perceived larger problems such as the aridity and scarcity of water. Although erosion is widespread in Namibia, it is not often severe or extreme (Strohbach 2000). During a land degradation survey across the country, Strohbach (2000) noted that up to 90% of sites contain some form of erosion, mainly slight or moderate sheet erosion. Land degradation mapping by Klintenberg & Seely (2004) indicated that while most of Namibia falls into the moderate to low degradation risk categories, there are some areas, especially in northern and north-west Namibia that are at high risk.

5.3.1 Sedimentation in dams

While some level of sedimentation of dams is expected under natural conditions and is generally planned for, elevated catchment erosion either incurs dredging costs or shortens the projected lifespan of dams and related infrastructure. Globally, anthropogenic sedimentation has been estimated to account for about 37% of the annual costs of dams (i.e. $21 billion) in terms of replacement costs (Basson et al. 2009).

Within Namibia, dams play an important role in the delivery of water to the population. While many farmers have small earth dams, there are also approximately twenty larger dams that service towns and larger settlements. The larger dams in Namibia such as Hardap (295 million m^3), Naute (83.6 million m^3) serve to not only provide water but also offer some form of flood control for downstream settlements. Other dams such as the Omdel dam have been specifically designed to allow silt to settle from flood water and then allowing the silt-free water to help infiltrate into the underground aquifer which is used for water supply (2030 Water Resources Group 2015).

The catchments for the dams within Namibia fall mainly within the central and southern regions of Namibia (Figure 5.3). The catchment for Hardap and Naute dams are the largest, whereas some of the dams close to Windhoek have only a few rivers feeding them. Most of these rivers are within farmland with minimal land transformation. The one large dam in northern Namibia has its catchment mainly within Angola. It is therefore likely that any sediment retention service being offered by the current natural vegetation cover is mainly occurring within catchments outside of Namibia.

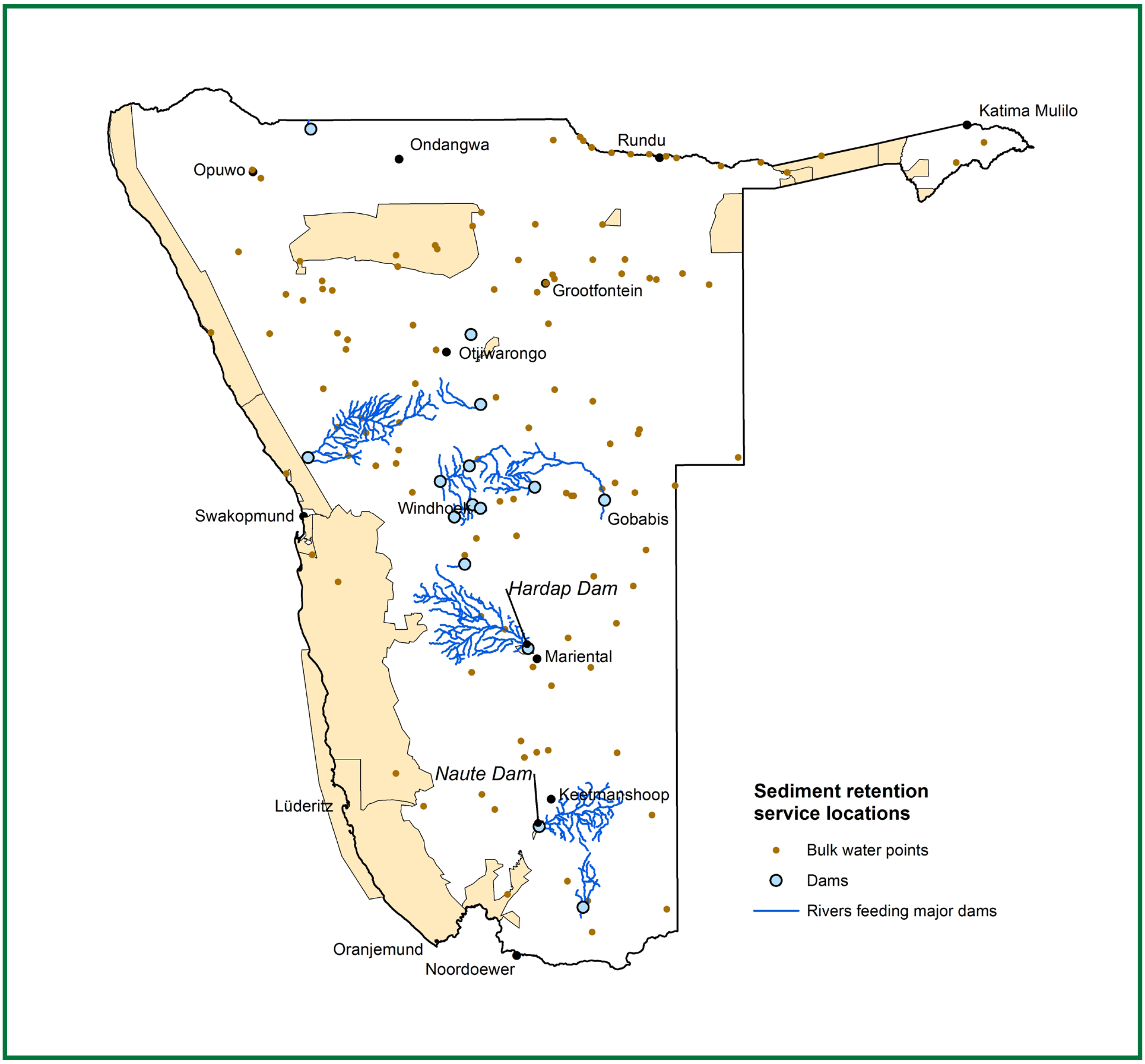
5.3.2 Other issues surrounding sedimentation

In the context of Namibia, excess sedimentation (if in the form of silt or clay particles) in rivers also have the additional issue of forming a clay crust along river beds which can then decrease infiltration into aquifers (2030 Water Resources Group 2015). Given the importance of aquifers in supplying Namibia with fresh water, this detrimental effect of sedimentation could also be significant.

The distribution of bulk groundwater points is much more widespread across Namibia. Which of these groundwater aquifers might be potentially influenced by increased sedimentation (and therefore decreased infiltration) along riverbeds need further research to be able to establish any benefit vegetation is having.

Unlike perennial river systems, there are no aquatic ecosystems along Namibia's ephemeral riverine systems, nor are there many estuarine systems. While perennial river systems may endure degradation due to increase sediment loads, this would not be the case for most of Namibia. The only sizeable ephemeral river system which drains into a perennial one is that of the Fish into the Orange River. Here there could be potential negative effects of increased sedimentation

Figure 5.3 Location of dams and bulk groundwater points across Namibia as well as the ephemeral rivers flowing into the dams



to the aquatic systems downstream. It is, however unlikely that the amount of sedimentation being retained by the sparse vegetation in these drier parts of the country would increase sedimentation meaningfully.

5.3.3 Valuing the service

In order to estimate the amount of sediment that is being prevented from being washed into the river network and ending up in dams we would need to model the flow of water and sediment for each catchment. Considering the importance of the timing of rain in determining the sediment run-off (due to season growth of vegetation), it would be imperative to use a model that works on a daily time scale rather than more simplistic annual average models. These models, however, are time and data intensive to develop.

The costs of sedimentation of dams could be estimated either as the replacement cost of lost storage capacity (e.g. through raising the dam wall or constructing a substitute dam at a new site to make up the reduction in capacity), or as the cost of dredging to remove the accumulated sediment. With respect to dams, often the replacement cost can be cheaper than dredging.

In order to value the lost capacity for groundwater recharge, river systems that would potentially suffer from having fine particles cap the riverbed under increased sedimentation would need to be identified. If these systems are ones where the groundwater aquifer it utilised, then the amount lost could be estimated and valued at the cost of water.

5.4 Water quality amelioration

The ability of wetlands and natural vegetation to remove nutrients, wastes and sediment has been recognised since the 1970s. There are a number of different process through which wetlands and vegetation remove nutrients and pollutants from the influent water (Figure 7). Wetlands are much more efficient at removing both sediment and nutrients from water than terrestrial landscapes, however they can still play a small role.

Nutrients that are introduced in dissolved form can be taken up directly by plants and incorporated into plant tissue as they grow. Most of the phosphorous that is introduced to wetlands is attached to sediment and settles to the bottom, where it can remain inactive (Brinson 2000). Because phosphate is associated with sediments (Brinson 2000), much of the load may enter wetlands during large flood events (McKee et al. 2000). These loads often become a permanent part of the bottom sediments, and wetlands with clay soils are particularly efficient at retaining phosphorus, even at low loading rates. Thus phosphate removal is expected to be higher in wetlands with low water velocities and high hydraulic roughness. Macrophytes also contribute to total phosphorus retention by enhancing sedimentation.

Nitrogen enters wetlands in the form of ammonia (e.g. from animal wastes) or nitrates (e.g. from fertilisers), and is removed by the nitrification–denitrification process (Saunders & Kalff 2001). Nitrification is the microbially-mediated oxidation of ammonium (NH4) to nitrite (NO2) and then nitrate (NO3). This process consumes oxygen and thus occurs in aerobic areas of the wetland. This occurs mainly in sediments with abundant organic matter that provides a carbon source for denitrifying bacteria. Inputs with low nitrate loads (e.g. from natural catchments) will require both aerobic and anaerobic conditions to nitrify and denitrify nitrogen inputs. Nitrogen, in any form, is also taken up from the soil by growing plants. Bacteria concentrations are reduced in wetlands by exposure to UV-light. The degree to which this occurs is linked to the duration of water retention within the system.

5.4.1 Water quality within Namibia

The ability of wetlands to perform water quality amelioration services depends on their area and type of vegetation as well as to their overall health and management. While natural ecosystems, especially wetlands can provide beneficial services, within Namibia such services are not readily demanded throughout much of the country. For large parts of the country water is extracted from groundwater reserves, where main water quality issues are to do with high levels of dissolved minerals and salts. These water quality issues arise from leaching of minerals into the rainwater recharging groundwater aquifers and are unrelated to the vegetative components of the ecosystems.

Due to severe water shortages in parts of the country during droughts, Namibia has taken to recycling and treating some of its grey water as well as desalination of seawater for human consumption. Again, these water sources do not benefit from any water quality amelioration services.

Areas in which wetlands exist which are likely offering the service of water quality amelioration include the wetlands and floodplain surrounding the perennial river systems along Namibia's northern and southern borders.

In the Caprivi and along the Kavango rivers, many people abstract directly from the river systems for access to drinking water (approximately 20% of people, NSA 2014a, b). Water in these areas when collected directly from the river is not treated and often poses risks to the consumers through water borne diseases as well as with collecting the water in areas where crocodiles and hippopotamus frequent. In these areas it is possible that any potential water quality amelioration services occurring in the rivers wetlands and floodplains is outweighed by the risk associated with both collecting and drinking the water. There have been large-scale upgrades to water infrastructure throughout the country which include abstraction and treatment from rivers such as the Kwando in the Caprivi. These treatment works stand to benefit from the water-treatment amelioration services provided by wetlands along the Kwando River as well as wetlands and vegetated landscapes higher in the catchment within Angola. Other wetlands and floodplain within eastern Caprivi might also be offering water quality amelioration services to downstream countries via the flow of water into the Zambezi.

Within the Cuvelai drainage basin, water is mainly piped through a canal from Calueque dam within Angola which is part of the Kunene River basin. There are a number of water treatment plants in this area which treat the water to potable standards. The water quality originating from the dam is considered unfit for drinking without treatment and the quality decreases with distance from the dam (Kuutondokwa 2008). The quality of the water in the Calueque dam is undoubtedly dependent on services provided by upstream landscapes in Angola where the water comes from. Any benefit of this service, although enjoyed by Namibia is actually attributable to Angolan ecosystems.

A small amount of water is also abstracted from the Orange River for Noordoewer and farms and mines along the banks. Again here any water quality amelioration services are being provided from ecosystems within South Africa.

Another water source which might benefit from amelioration services include water abstracted from dams. While the water quality in Namibia's dams is considered fairly good, occasional turbidity problem and algal blooms do occur and water needs to be treated prior to becoming safe for human consumptions. Were the dam catchments degraded, water quality would be expected to decline and turbidity and the frequency of algal blooms increase. These would increase the treatment costs associated with treating the water. Similar to the sediment retention value, due to the lack of wetlands along the ephemeral rivers, this value is mainly assigned to the landscape. Once again it is highly dependent on the timing of the rainfall within the wet season as the cover of vegetation will make a big difference in the amount of sediment retained, and as a consequence, the water quality.

Figure 5.4 on the next page gives an indication of where the value of water quality amelioration services might be benefiting people within Namibia. In addition to these areas, some vegetated areas surrounding smaller farm dams might also be contributing to improved water quality at smaller scales.

5.4.2 Valuing the service

In order to assign a value to the water quality amelioration service of vegetated landscapes and wetlands across Namibia there are a number of data gaps that would need to be filled. First we would need to identify location of current water treatment works across Namibia and access their data on water treatment costs in relation to the incoming water quality.

Hydrological based modelling techniques could then be used to model the effect of removing the retention ability of wetlands and the landscape and the resultant water-quality at abstractions points and/or dams. Using the cost function we could then predict the increase in treatment costs that would be associated with a loss in function of the natural ecosystems.

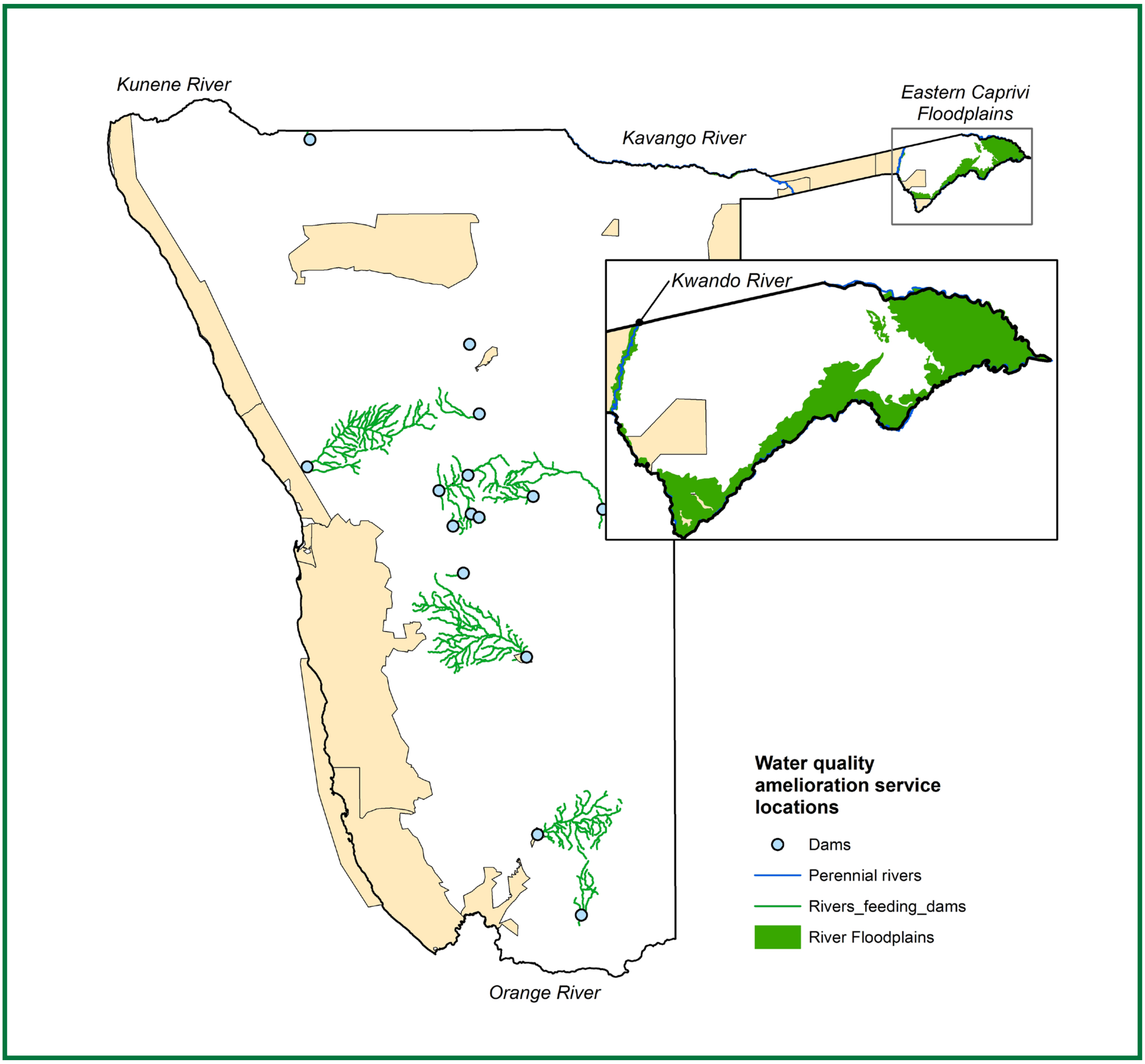
5.5 Groundwater recharge

Ground water supplied almost half of the available freshwater within Namibia in 2000 (Christelis & Struckmeier 2001). During dry seasons, periods of drought and water scarcity, this percentage can rise. More than 100 000 boreholes have been drilled across Namibia, although only approximately only half of these are potentially productive (Christelis & Struckmeier 2001). Unlike storing surface waters, ground water reserves have the benefit of avoiding the extremely high evaporation rates found throughout the country. These underground water resources must be recharged from rainfall and other surface waters if they are to be sustainably utilised.

Groundwater recharge can be defined in a broad sense as the addition of water to a groundwater reservoir (Xu & Beekman 2003). When rain falls most of it is evaporated, drains into rivers and streams or is utilised by vegetation (Mendelsohn et al. 2002). The water that does fall onto the ground (and even some of the water that flows through rivers and stream) infiltrates through the unsaturated zone will eventually reach the water table and becomes part of the groundwater where it is stored (van Vuuren 2011). Water in the uppermost layer of the unsaturated zone is known as soil moisture and although it cannot be abstracted, it is extremely important for the maintenance of vegetation and terrestrial ecosystems (van Vuuren 2011).

The quantity and quality of groundwater recharge is largely dependent on land use, vegetation cover, soil texture, slope and the physical properties of the local aquifers (CGIAR 2015). Vegetation cover has a significant influence on how

Figure 5.4 Location of areas where water quality amelioration services might be occurring throughout Namibia



much water drains into the soil and how much is lost to runoff. Land degradation, which is characterised by declines in soil formation and composition, and bush encroachment, are becoming serious concerns across Namibia, especially because it is now evident that the rate of groundwater recharge has reduced in these areas (Colin Christian & Associates cc 2010, NNF 2016).

Recent studies have shown that in certain areas of Namibia where bush encroachment (undesirable thickening of woody species in savanna ecosystems) has increased, infiltration and groundwater recharge has decreased. This is a result of certain types of encroacher bush species that have extensive woody root systems that dominate the upper soil layers, preventing water from reaching the water table below. Increases in bush encroachment lead to higher levels of evapo-transpiration which reduce groundwater recharge (Colin Christian & Associates cc 2010). The degree to which groundwater levels have fallen varies across the country, due to different harvesting rates, the severity of bush encroachment, the size of local aquifers and the ease at which they can be recharged (NNF 2016). In certain areas it has become clear that overexploitation of groundwater resources has occurred and that significant recharge only occurs in years that have above average rainfall (NNF 2016).

Recharge rates are very difficult to measure because they vary so widely in time and space and are dependent on so

many different environmental and geophysical factors (CGIAR 2015). In Namibia where up to 80% of the population rely on groundwater reserves, understanding and accurately estimating groundwater recharge and groundwater balances is very important for the sustainable management of this resource. There are currently studies underway to understand more about groundwater recharge and bush encroachment, such as the Southern African Science Service Centre for Climate Change and Adaptive Land Use (SASSCAL) Integrated Science Plan looking at the impact of bush encroachment on ground water resources in Namibia. More needs to be done to bridge knowledge gaps, such as collecting data (hydrological, geological etc.) that is required to fully assess recharge rates at a national level. While there may be very good information about local scale water schemes or specific study areas, the knowledge about the situation and status of groundwater resources at the national level is seriously lacking.

5.5.1 Aquifers in Namibia

Ground water within Namibia is made up of a series of different aquifers. Many aquifers are relatively isolated rather than interconnected throughout the country. The type of aquifer depends on the underlying geology. Some aquifers can be porous and large areas can be connected and there can be a directionality of flow across different regions of the countries, whereas other aquifers can be old, deep and stable, receiving little recharge from the surface rains. Across Namibia aquifers can broadly be divided into fractured, fissured and karstified aquifers and porous aquifers.

Fractured, fissured or karstified aquifers exist in hardened rock where water is held in fractures or fissures in the rock. In these aquifers the rate of flow of water through the matrix into the fissures can be slow, however the rate of flow once in these gaps is relatively fast, hence these aquifers can be very productive, but recharge rate depend how close fractures are to the surface. If close, recharge can be rapid and so can transport of pollutants as there will be little filtering effect. Recharge in these aquifers often has to happen at a local scale. Porous aquifers in comparison the water is held between the soil particles which acts not dissimilar to a sponge. In these types of aquifers, water infiltrating into the aquifer far from the abstraction point can still flow through the medium to help recharge the aquifer in areas not immediately close by. Of course each aquifer is different and may not act in a predictable way. To be able to fully understand any aquifer, the detail of underlying geology must be known, which can be difficult at large scales.

Seven major aquifers in Namibia include the Karst, Omdel, Kuiseb, Windhoek, Strampreit and Koichab aquifers (Figure 5.5 on page 51). Some of their main characteristics are described in Table 5.1 on page 67, including detail about how they are recharged, which is not always fully understood

Monitoring the state of groundwater resources and being able to actively manage both recharge and abstraction is likely to increase the longevity and sustainability of the resource use. Namibia currently has in place many regulations and techniques to try and limit non-essential abstraction, but also assist groundwater recharge where possible.

One such method involves the preferential use of surface water when it is available preferentially (thereby giving aquifers time to recover and limiting evaporative losses due to surface water standing for long periods of time). Another technique involves creating dams specifically to help increase infiltration into aquifers by allowing fine particles to settle out before pumping into infiltration dams where the underlying geology allows for increased infiltration (e.g. Omdel dam; 2030 Water Resources Group 2015). Groundwater banking is yet another technique used which involves pumping surface water of similar quality directly into boreholes. NamWater in Windhoek is working towards being able to use these techniques to help assist recharge of the Windhoek Aquifer (van Vuuren 2011).

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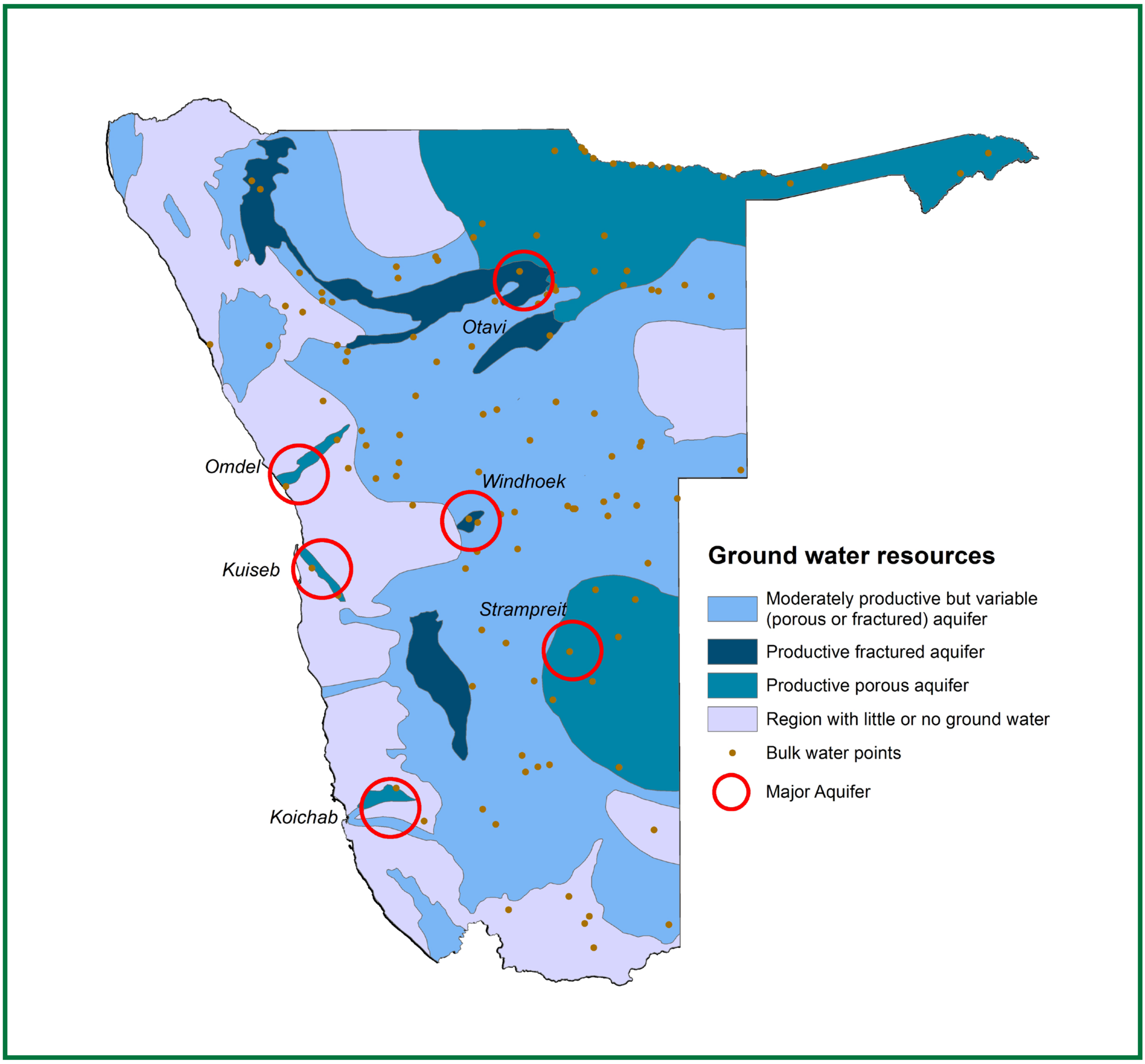
Figure 5.5 Location of major groundwater resources occurring throughout Namibia (Source: Mendelson et al. 2003)



5.5.2 Valuing the service

The economic value of groundwater resources in Namibia is huge. Many industries as well as a large proportion of the population rely directly on these water sources. The total economic value of the resource however should not be confused with the value of groundwater recharge attributable to the ecosystem, of which might only be a fraction of the total value of ground water yield.

Like other provisioning services, the groundwater resources have a sustainable yield which can be quantified as the amount that can be abstracted from the resource without comprising the functioning of the resources and ecosystem. While this sustainable yield should equal the amount of recharge occurring, not all of the recharge is mediated through ecosystems. In order to estimate the value to groundwater recharge attributable to Namibia's ecosystems, we would need to have data on what proportion of recharge is assisted by the presence of ecosystems. The value of this service could be either estimated as the value of the price of water that is recharged, or by the cost of replacing that level of groundwater recharge through engineered solutions such as pumping water directly into the aquifer or creating infiltration dams.

Table 5.1 Main aquifers within Namibia as well as known information on recharge and the likelihood that vegetation contributes to the rate of recharge

Aquifer Name	Type	Understanding of Recharge	Vegetation type	Contribution of vegetation
Otavi	Karst	Abstraction exceeds recharge	Mixed woodlands	High*
Omdel	Porous	Natural infiltration limited by silt deposition in river, artificially supplemented by Omdel dam	Shrubland – desert gradient	Medium
Kuiseb	Porous	Abstraction exceeds recharge	Desert	Low
Windhoek	Fractured	Naturally fast recharge and little loss to areas outside city basin. Plans to artificially supplement recharge	Shrubland	High*
Strampreit	Artisanal Porous	Fast recharge, but estimated to be lower than abstraction.	Open woodland	High
Koichab	Porous	Not well understood, but levels appears stable	Sparse shrubland and grassland	Low

* Potentially complicated by bush encroachment (see Box 5.1)

5.5.3 Simplified groundwater model

A preliminary groundwater recharge model was constructed based on best available data. While there is still much research required and detailed studies needed to be able to estimate the true value of groundwater recharge at a national scale, this estimate at least provides an indication of the areas in which groundwater recharge is likely to be significant and where the natural ecosystems are providing.

Sustainable yield was estimated using a set of assumptions based on rainfall, soil porosity and vegetation types. We assume that the percentage of rainfall that infiltrates into ground across Namibia is approximately 2% (Heyns et al. 1998). Soil types were broadly divided into porous sand-like soils and non-porous soils based on the soil map of Namibia (Mendelson et al. 2003). This percentage infiltration was adjusted up or down based on the types of soil porosity. Vegetation types were grouped into desert, sparse vegetation, savanna with <10% canopy cover and savanna with >10% canopy cover. We assumed that intermediate tree cover maximised groundwater recharge based on curves in Ilstedt et al. (2016).

The model used borehole yield data from Mendelson et al. (2003) to estimate the distribution of the demand for groundwater across Namibia. If the borehole yield was greater that the estimated sustainable yield, then the sustainable yield was used. On the other hand if the actual yield was less than the sustainable yield, then the actual yield was used. This simplified model doesn't consider connectivity between aquifers, or deep and fractured aquifers and works of the simplified assumption that rainfall and infiltration occurring within the immediate vicinity (5x5 km grid) affects the availability of groundwater locally. The value of the water was taken as the raw cost per m^3 of extracting groundwater with the Western Cape in South Africa. If abstraction is occurring from deeper, older aquifers, it is likely that the sustainable yields could be higher, but also that less of the value is attributable to the presence of vegetation. In order to more accurately estimate the contribution of vegetation to groundwater recharge in Namibia, detailed scientific studies would be necessary.

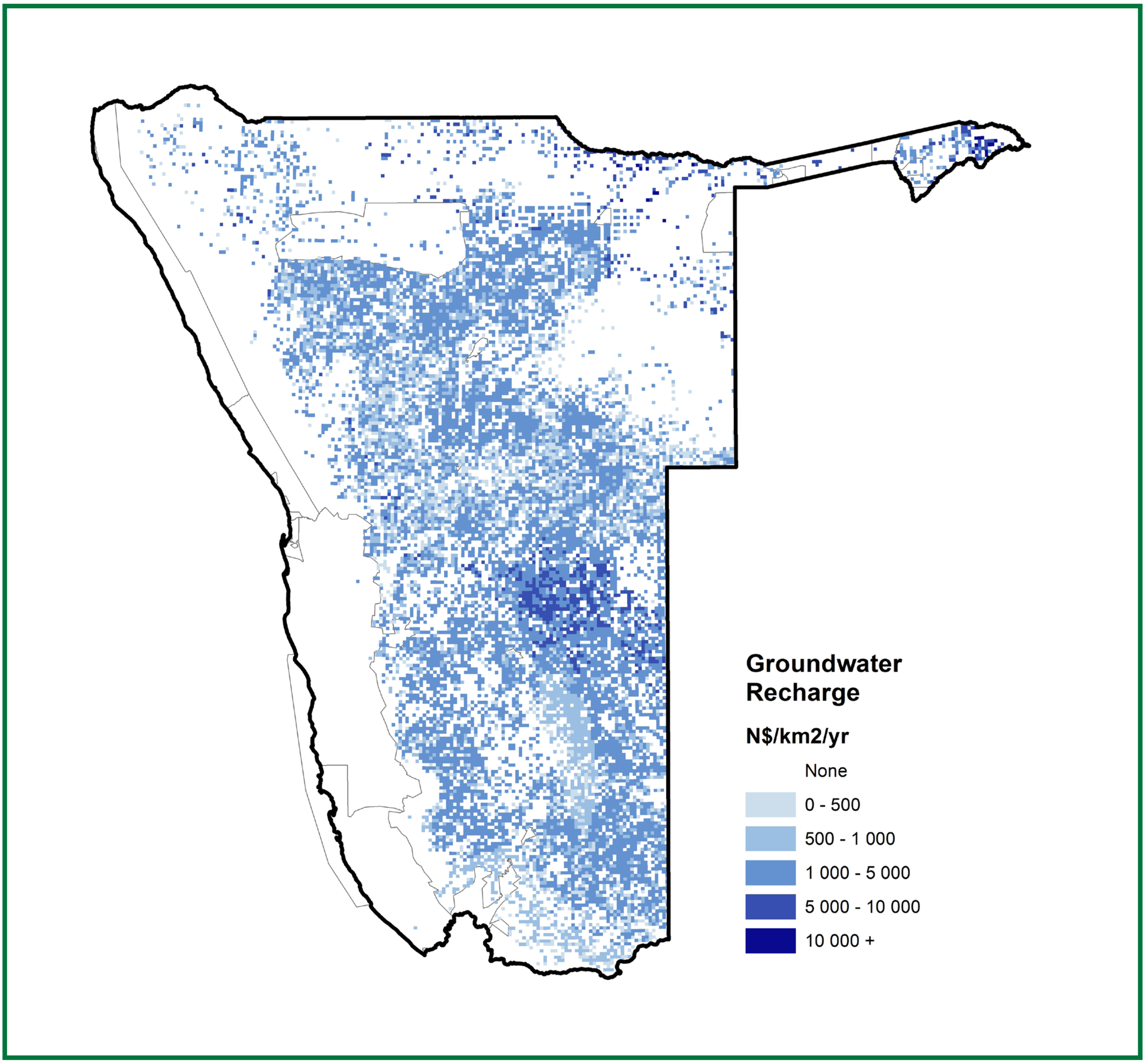
The total value of this service was estimated to be approximately **N$448 million/year**, most of which was concentrated in commercial farmland where there is an abundance of farmers utilising groundwater resources.

5.5 Carbon sequestration and storage

Climate change caused by increases in the emissions of greenhouse gases will carry a cost of about 2 – 7% of Gross Domestic Product (GDP) in different parts of the world by 2050 (Fankhauser & Tol 1997). Natural systems are understood

to make a significant contribution to global climate regulation through the sequestration and storage of carbon. About half of the biomass of vegetation, both above and below ground, comprises carbon. Furthermore, carbon accumulates in the soils as a result of leaf litter. When natural systems are degraded or cleared, much this carbon is released into the atmosphere, especially if the degradation is for fuel wood production or due to burning for grazing (Hoffa et al. 1999). These emissions contribute to global climate change, which is expected to lead to changes in biodiversity and ecosystem functioning, changes in water availability, more frequent and severe droughts and floods, increases in heat-related illness, and impacts on agriculture and energy production (IPCC 2007).

Figure 5.6 Estimated of the value of groundwater recharge being mediated by ecosystems throughout Namibia)



These impacts will affect economies and human wellbeing on a global scale, but more so in developing countries that are more reliant and land and natural resources (Tol 2012). Adaptation to these changes could come at a high cost. The conservation and restoration of natural systems thus helps to reduce the rate at which greenhouse gases accumulate in the atmosphere and the consequent impacts of climate change. This is a global benefit.

Namibia has shown much willingness to help tackle climate change though reducing its emissions in support of international efforts such as the United National Framework Convention on Climate Change (UNFCCC). Namibia currently aims to reduce its Greenhouse Gas emissions by 89% by 2030. The main avenue through which Namibia aims to achieve this level of emissions is through changes in agriculture, forest and other land uses including reducing deforestation, reforesting and restoring grassland (Republic of Namibia 2015).

Within Namibia, the matter of carbon storage and deforestation/reforestation as a technique to combat climate change is somewhat more complex than in many countries due to the land degradation issue surrounding 'bush encroachment'. Within Namibia, as well as a few other southern African countries, the densification of woody species across rangelands is causing a number of problems to livestock farming, as well as having a number of negative effects on the delivery of different ecosystem goods and services. However, the increase in density of woody species does increase the carbon stored across the landscape. Removal of these encroaching species for landscape restoration does therefore come at a cost to the carbon storage value of Namibia. The issue of bush encroachment, the effect on the delivery of ecosystems service and the trade-offs between them are explored in Box 5.1 on page 71.

Carbon storage and sequestration is typically much lower for arid regions than areas of high vegetative productivity. Carbon storage has been shown to increase with organic soil content and vegetative cover, suggesting that the arid coastal belt is far less important for carbon sequestration than woodland and savannah in other parts of Namibia (Lal 2000; Su et al. 2003). The total estimated woody biomass carbon storage within Namibia's as estimated by Turpie et al. (2010b) using empirical data from the forest accounts developed by Barnes et al. (2005) was 97 million tonnes. This does not however include forest biomass and is therefore an underestimate.

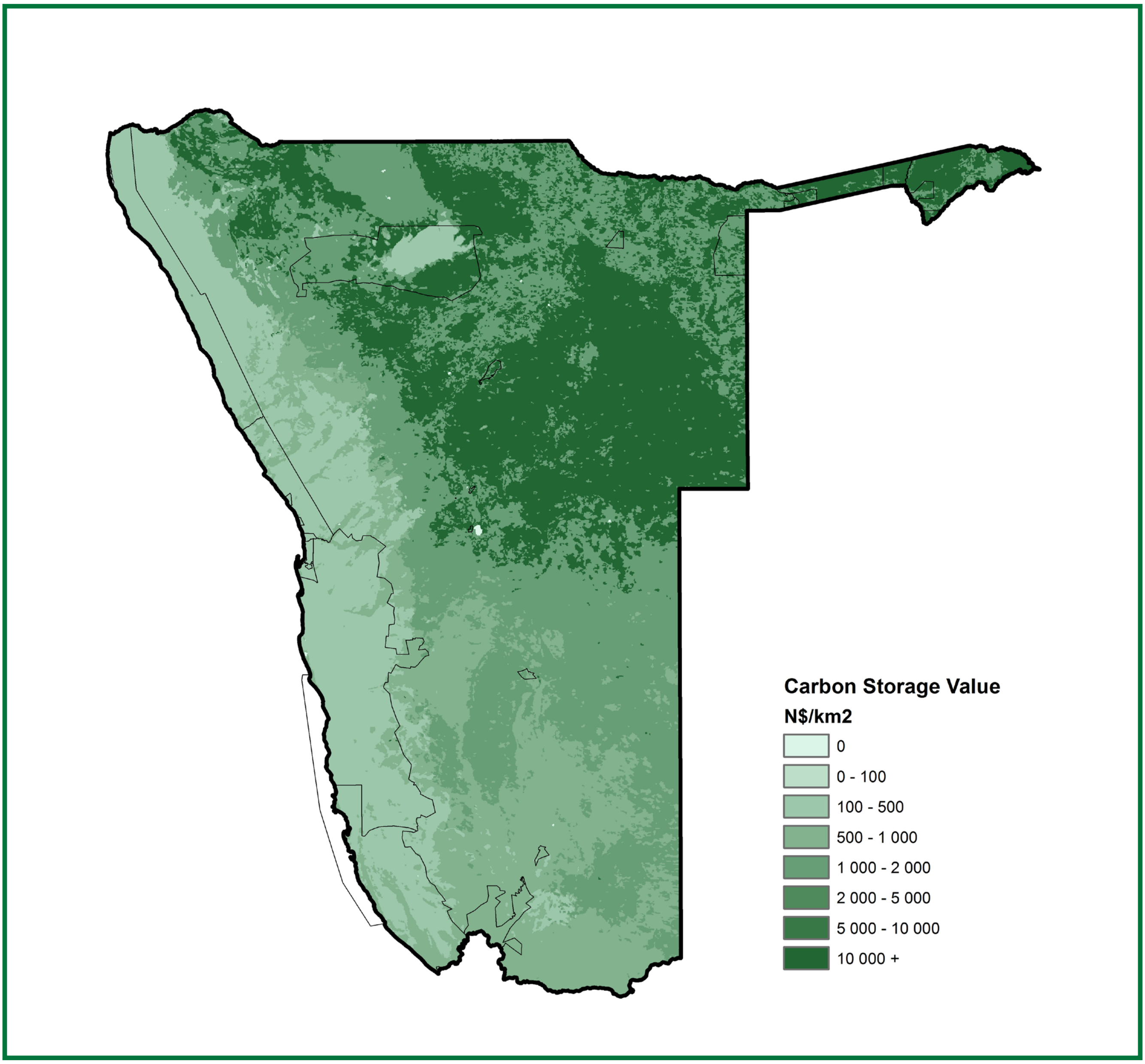
The distribution of carbon storage across Namibia was mapped based on the IPCC-Tier 1 Global Biomass Carbon Map for the year 2000 (Ruesch &Gibbs 2008). The capacity for carbon sequestration and storage varies between different types of ecosystems and in different locations. This map estimated the carbon stored in both above and below ground living vegetation based on vegetation types identified through satellite imagery in addition to scientific literature. The result is a map of living biomass carbon density across Namibia (Figure 5.7 on the next page).

It was estimated that approximately 1.3 billion tonnes of carbon are stored within Namibia's vegetation. The highest densities occur in the north-eastern parts of the country where dense bush (natural as well as that affected by bush encroachment) occur. The coastal and southern areas have the lowest carbon densities due to the sparse vegetation that occurs there.

The benefit to Namibia of maintaining its ecosystems is the sum of local damage costs avoided and sale of carbon credits to the rest of the world. Estimates of the global social cost of carbon vary greatly; the most recent estimate placed the social cost of carbon at US$31.25 per ton of CO2 (in 2010 USD; Nordhaus, 2017), of which an estimated 3% would be borne in Africa. The cost that would occur to Namibia would be proportional to its GDP contribution to Africa, scaled by level of vulnerability to climate change. The Notre Dame Global Adaptation Initiative (ND-GAIN) vulnerability index was used to scale GDP contributions across Africa. The vulnerability index measures a country's exposure and sensitivity to negative impacts of climate change. The overall vulnerability index is scored based on six life-supporting sectors; food, water, health, ecosystem services, human habitat and infrastructure. Based on this index, it was estimated that Namibia is likely to bear only 0.002% of the global social cost of each ton of carbon emitted. While developed countries emit more carbon, developing countries are expected to incur proportionally greater costs in terms of percentage of GDP.

Thus, while the global damage costs that this amount of carbon could produce are over N$2 153 billion world-wide, the damage costs to Namibia resulting from a loss of the carbon stocks nationally might only be approximately **N$38 million per annum**.

Figure 5.7 Distribution of value of vegetative biomass carbon density across Namibia. Based on the IPCC-Tier 1 Global Biomass Carbon Map for the year 2000 (Ruesch &Gibbs 2008)



5.6 Refugia

Many different species of animals in Namibia have large ranges, within Namibia as well as across its borders. Value may be derived from these animals at any point within their range, whether tourism value, biodiversity value or direct use value. For example one species might have tourism value when in location A, however not in another area B. Even if this value is only realised in one area (A), the fact that the animals rely on area B for habitat, some of the value derived from A can also be attributed to area B.

Important Bird Areas and proposed important bird areas across Namibia give indications of sites that are important to global populations of bird (Simmons et al. 1999). There are a few sites in particular which are of exceptional importance to Palearctic migrant waterbirds – these include Sandwich Harbour and Walvis Bay Lagoon. This complex set of wetlands on average can support over 150 000 water birds in summer. For up to 25 species, counts have exceeded the 1% threshold for the flyway populations. For one species, chestnut-banded plover, some counts have routinely exceeded 50% of the flyway population estimates. These wetlands are the most important wetland at the southern end of the East Atlantic Flyway (Wearne & Underhill 2005).

Box 5.1 The effect of bush encroachment on ecosystem services and the economics of de-bushing in Namibia

Bush encroachment affects an estimated 26-30 million hectares of land in Namibia and it thought to have increased significantly over the past few decades. Overgrazing is thought to be a key driver of bush encroachment, but the displacement of browsers by livestock, the suppression of high intensity fires due to cattle farming, rainfall and its variability, and increased atmospheric CO2 concentrations are also likely contributors.

Bush encroachment has the potential to impact a range of different ecosystem services the most important within the Namibian context include livestock production, groundwater recharge and tourism, as well as biodiversity. The majority of the ecosystem services are negatively impacted by increased bush density. However, for some, the relationship is less clear and for a select few, like carbon storage, the relationship would be positive.

NNF (2016) analysed the potential effects of a programme designed to combat bush encroachment on the delivery of ecosystem services. A summary of the effects on ecosystem services are presented in (Table 5.2). These relationships highlight the trade-offs that often exist between different services.

Maximising one ecosystem service (such as carbon storage) may come at a cost to other services. For the ecosystem services that could be valued, NNF (2016) were able to conduct a cost-benefit analysis for the case of de-bushing encroached areas across Namibia. The cost-benefit analysis used these values to estimate the potential net benefits of a programme of de-bushing, compared with the business-as-usual scenario of no de-bushing, over a 25-year time horizon. These results suggest that de-bushing could make a considerable contribution to Namibia's welfare and economy.

Furthermore, as it is likely that many of the unquantified ecosystem services would be positively affected by de-bushing, it is reasonable to expect that there is upside risk to these estimates.

Further value estimates from Stafford et al. (2017) were able to more accurately pinpoint the value of de-bushing in terms of increased grazing capacity, decreased loss of groundwater resources to the thickened vegetation and value added through timber products harvested. Stafford et al. (2017) argue that if the burning of wood fuels from the de-bush replaces coal energy production there will be a net decrease in carbon emissions. However, this may not offset the loss of carbon stocks form the rapidly-growing woody biomass cleared.

So there is likely to be a net loss in carbon due to the loss of woody biomass as well as the change in land use to include high numbers of livestock. The total ecosystem service benefits from restoring the land were estimated as having a Net Present Value of close to US$6 billion (over a 25 year period with 6% discount rate).

This value is considerable compared to the cost of a de-bushing programme. The majority of this value comes through estimated savings to groundwater resources.

Table 5.2 Main effects of a de-bushing programme on the delivery of multiple ecosystem services within Namibia (Source NNF2016)

Provisioning Services	Example	Direction of impact	Notes
Agriculture; reared animals and their outputs	Beef production	+	Higher grass:bush ratio and increased carrying capacity from de-bushed areas
Plant-based resources	Charcoal &	+	By products of de-bushing can be used firewood production
Wild plants, algae Devil's Claw)	INPs (e.g.	+	But likely only up to a point, and their outputs after which the impact may be negative. Only relevant over a limited area. Valuation requires further research.
Wild animals and their skins	Game meat,	+/-	Depends on species and whether outputs there is a move towards conversion to wildlife-based land uses. Further data required.
Fibres and other materials for direct use or processing	Materials for	+	Depends on use of material de-bushing. Requires further data.
Regulating Services			
Global climate regulation by reduction of greenhouse gas concentrations	Carbimpaon sequestration	-	Change from grass to woody vegeta tion increases both above ground biomass, as well as the storage of soil organic carbon. De-bushing will likely lower the stored carbon. But fuel production from de-bushing might be offset some of this loss by decreasing dependence on coal-based energy sources.
Control of erosion rates and sediment retention	Control of soil erosion	+	Depends on the method of de-bushing. However, areas with a higher grass:bush ratio should have lower erosion and higher sediment retention.
Hydrological cycle and water flow maintenance	Groundwater recharge	+	Increased bush density decreases groundwater recharge, de-bushing will therefore increase groundwater recharge. But further research is required.
Cultural Services			
Experiential use of plants, animals landscapes	Wildlife viewing	+	Less dense bush is preferred by tourists and increases wildlife viewing opportunities. & Valuation requires further research regard-ing the impact of de-bushing
Physical use	Trophy hunting	+	Similar to wildlife viewing, less dense bush could promote better wildlife finding experiences, as well as increasing carrying capacity for a range of grazing species.

Ephemeral pans across Namibia also play an important stop-over role for Palearctic migrants as well as regional populations of both lesser and greater flamingos. These pans do not provide habitats while dry, but bird populations are known to follow rain fronts and take advantage of these habitats when they fill with water (Simmons et al. 1997). Pans of particular significance include the large Etosha Pan which provides breeding sites for lesser flamingos, white pelicans and chestnut-branded plover (Simmons et al. 1999) and pans within Bushmanland which provide a stopover on flamingo migration routes to Makgadikgadi Pans in Botswana (McCulloch et al. 2003).

Desert-adapted mammals such as lion, elephant and giraffe within the Kunene region are a major draw card for many tourists. These animals range over very large areas as resources are widely distributed. While the tourism value of these animals may only be realised in one or two areas where sightings occur often, these animals require much larger areas to sustain their populations.

Similarly, in the Eastern Caprivi, wildlife moves between countries, different reserves and across communal areas throughout the year (e.g. Elephants, von Gerhardt-Weber 2011; Zebra, Naidoo et al. 2014). The entire region, including natural habitats across borders in Angola, Zambia and Botswana all contribute to maintaining the populations that are of tourism value within the protected areas such as Bwabwata, Mudumu and Nkasa Rupara National Parks.

Valuation of this service is very uncommon in many ecosystem service valuation studies given the data requirements. If one was to try and value this ecosystem service we would need to estimate:

1. Which species are providing value in one area but are also dependent upon another area for part of their life cycle;

2. What the value of these species is in the area they provide value (locally and internationally);

3. Decide how the value should be spread between the area the animals provide value and the other areas they are dependent upon; and

4. The extent to which the value is affected by a change in quality of the refugia.

It is important to not double count values when determining this value. For instance, here we have valued the tourism value of different areas across Namibia. If we were to assign this value to areas where the species that provide tourism value (such as large mammals) spend other seasons, then the value would be assigned twice and therefore be overestimating the total value of ecosystem value. Here for all species providing tourism value we assume that the values have been captured in the tourism value mapping.

However, it is important to consider that these values may in reality are spread beyond just the area where the wildlife viewing takes place. We have not attempted to value the biodiversity value of these species. Such values become more relevant for local scale analyses, e.g. of areas like the Okavango delta (Turpie et al. 2006).


Picture: Gys Reitz

6

Ecosystem services in relation to land tenure

6 Ecosystem services in relation to land tenure

The total value of ecosystem services valued in this study were estimated to be in excess of **N$13 billion per year**, or roughly 9% of Namibia's GDP (World Bank 2016). These ecosystem services were not equally distributed across the country or across the different land tenure types. The main drivers of the distribution of value differed between different services however rainfall (and therefore productivity) as well as human population played large roles in determining the spatial pattern. North-eastern Namibia has the highest rainfall, highest plant biomass as well as access to permanent sources of water. These areas support denser vegetation and generally higher populations of game than the more arid regions in the south and west of the country. These northern areas, as well as those along Namibia's northern border, also support the highest densities of human populations. These populations drive higher demand for many of the goods and services, which is what gives many of these goods and services their value.

The value of provisioning services such as woody resources, food and medicines were highest in communal areas where there is a higher demand for such services. Other provisioning services like fodder and game meat production were highest on freehold land where free-roaming game numbers are higher and commercial livestock is the main economic activity (Table 6.1). Regulating services like groundwater recharge was mainly related to porous soils as well as demand through the distribution of boreholes and was therefore highest on freehold lands were landholders have sunk boreholes to provide water for cattle. Climate regulating services such as carbon storage was highest in communal lands which span the high rainfall regions of Namibia where vegetation biomass is the greatest. The distribution of tourism value was spread relatively evenly across all land tenure types, but was highest in Protected Areas (Table 6.1).

6.1 Communal areas

Within Namibia's communal land the bulk of the value of ecosystem services is derived from provisioning services, fodder production and tourism. The total value of services that were valued and mapped were in the order of N$6.8

Table 6.1 Distribution of value of ecosystem services across main land tenure types within Namibia

Ecosystem Service		Freehold land N$	Communal land N$	Protected Areas N$
Provisioning	Woody resources	12 199 064	1 862 132 519	
	Non-woody resources	7 765 720	740 121 237	
	Food and medicines	10 014 286	667 705 857	
	Inland fisheries		109 392 445	
	Livestock fodder	2 281 944 143	1 518 055 857	
	Game (meat)	93 564 949	10 097 433	
	Game (trophies)	77 580 793	1 276 826	
Amenity	Tourism (nature-based)	1 208 450 704	1 812 676 056	2 178 873 239
Regulating	Carbon storage	16 313 745	18 901 891	2 784 362
	Groundwater storage	372 886 114	65 700 607	9 276 612
Total		**4 080 719 518**	**6 806 060 728**	**2 190 934 213**

billion per year. Over 95% of the value of woody resources, non-woody resources, wild food and medicine and inland fisheries is situated within communal land. This high value is a result of the high populations in these areas as well as the high reliance on natural resources that make a significant contribution towards household livelihoods. Woody resources in particular make up a large portion of this provisioning value, especially in the more forested areas in the north-east of the country.

Fodder production within communal lands accounts for approximately 40% of the national value. Even though livestock ventures on communal land are often not as profitable as those on freehold land, these livestock populations are significant providing an important source of income for rural households. This value is however limited by the levels of overgrazing, particularly in the northern communal lands. This value is also limited by the low carrying capacity in the southern communal regions. The value of fodder was lower than carrying capacity in the communal areas near Tsumkwe in the north-east. The population density in these areas are much lower and therefore many of the natural resources are not fully utilised, which is likely a result of a lack of permanent water source to support large livestock populations. Game production within communal land is limited to conservancies that have hunting partners and those areas where game is still present. The value is therefore not nearly as high as on freehold land.

The amenity value of communal areas, while less than that of protected areas, accounts for almost 30% of the overall value of ecosystem services on communal land. The communal areas of Namibia contribute 35% of Panoramio photos across Namibia outside of urban centres. The highest concentrations are found in Caprivi along the Chobe and Zambezi Rivers as well as along popular tourist routes in Damaraland and Kunene.

The value of the regulating services within communal land is mainly comprised of agricultural support, carbon storage and flood attenuation. Agricultural support potentially holds large value to individual subsistence farmers across the extensive areas cleared for farming in communal lands that grow small scale fruiting crops. The flood attenuation service offered by wetlands is of potentially large value in the Caprivi, however this value is realised further downstream and not in Namibia. Carbon storage within the communal lands accounts for almost 50% of the national value due to the vast wooded areas in the north-east of the country.

6.2 Freehold land

Ecosystem services on freehold land were estimated total over N$4 billion per year. However there are a number of regulating services that could not be valued during this study and whose values could be substantial.
There was an apparent separation of the north-central and southern freehold farmlands in terms of the ecosystem services they provided as well as the overall value of these services. The northern areas had much higher total values which could be contributed to the fodder and game provisioning values. These north-central freehold farms enjoy higher rainfall and productivity and therefore maintain higher game populations and greater grazing capacity. In addition the north-central farmlands were often grazed much closer to carrying capacity (as opposed to communal lands which were often over-grazed), this led to maximisation of this value in these farmlands. Over 90% of the game meat hunting value and approximately 98% of the trophy hunting value was derived in freehold land. Most of this value was observed in the northern half of the country.

Freehold land in the southern part of the country is much drier with a much lower carrying capacity for both livestock and game. The main ecosystem services delivered in these regions were water-related services. Ground water recharge was of highest value in the sandy soils of the Kalahari where groundwater abstraction is common and infiltration relatively high. The sediment retention and water quality amelioration values in the freehold land were concentrated in the Fish River catchments. Tourism value was lowest in the freehold land areas compared with communal land and protected areas. Tourism hotspots were located in areas bordering high value tourism areas such as national parks.

Fodder production accounted for more than half the value on freehold land. It is important to recognise the link between livestock and game production and the production of fodder from functioning rangelands. Without this contribution of value, the commercial livestock sector would no longer be economically viable.

6.3 Protected Areas

Protected areas, despite maintaining good stocks of wildlife and woody resources have little monetary value for provisioning services as the harvesting of such resources from protected areas is largely prohibited. These areas do however provide support to regional biodiversity and can help maintain the value of ecosystem services in the surrounding areas. The amenity value of Namibia's Protected Areas is significant. The Protected Areas provided 42% of photos taken across of Namibia outside of urban centres. The highest concentrations of photos were along the main tourist roads between the three campsites within Etosha as well as the Waterberg Plateau and the area surrounding Swakopmund, the Namib-Naukluft National Park as well as the Hobas lookout point in Fish River Canyon.

Regulating services provided by the Protected Areas include flood attenuation is the Caprivi Parks, some sediment retention and water quality amelioration value in parks near Windhoek and Khomas region. The carbon storage value is by far the most important regulating service provided by Protected Areas.

The distribution of value of the different ecosystem services across each of the protected areas is not consistent. The highest ecosystem service values were found to be within Etosha National Park. This is partly due to the large size of the park, which helps give the park its high carbon storage value, but also due to its wildlife and popularity as a tourism destination. With exception to the Bwabwata National Park, most other protected areas had low carbon storage values because they are located in arid and semi-arid areas with low rainfall and as result contain low carbon biomass stocks.

Table 6.2 Distribution of carbons storage, groundwater recharge and leisure tourism value across Protected Areas within Namibia

Protected Area	Carbon Storage N$	Groundwater Recharge N$	Nature-based Tourism N$
Skeleton Coast Park	50 965	0	28 622 468
Cape Cross Seal Reserve	11	0	4 895 050
Dorob National Park	28 814	0	306 080 054
Sperrgebiet National Park	89 350	38 064	124 194 950
Namib-Naukluft Park	176 565	1 387 888	723 015 521
Hardap Recreation Resort	2 181	323 516	1 651 153
Naute Recreation Resort	1 428	122 191	1 397 860
Etosha National Park	1 287 314	3 703 496	835 401 101
Waterberg Plateau Park	38 989	133 377	9 300 236
Nkasa Rupara National Park	42 794	0	9 526 112
Daan Viljoen Game Park	3 457	140 328	4 647 972
Gross Barmen Hot Springs	33	41 236	227 094
Von Bach Recreation Resort	2 590	68 743	980 454
Khaudum National Park	184 255	333 824	2 890 929
Mangetti National Park	13 315	544 652	377 725
Ai-Ais Hot Springs	27 036	307 533	76 921 913
Bwabwata National Park (all areas incl. Mahango)	769 428	1 690 512	42 373 473
Mudumu National Park	65 835	441 251	6 369 175
Total	**2 784 360**	**9 276 611**	**2 178 873 240**

7

Degrading processes affecting ecosystem services in Namibia

7 Degrading processes affecting ecosystem services in Namibia

The areas where values of ecosystem services are highest (mostly due to high demand for such services) are also often the areas that are most at risk of degradation due to over-exploitation. This fine balance between sustainable use and over-exploitation is hard to maintain. In our analyses we have tried to adopt the approach of estimating sustainable yields and only valuing the service up until the maximum sustainable yield. This approach is preferable to simply valuing the degree of utilisation, as it can often be at levels above the sustainable yield. In reality, however, the sustainable yield is not a static thing. Sustainable yields can change from year to year dependent on factors such as rainfall, but also can be undermined in the long term through degradation and overexploitation. As such static analyses like the current study need to be updated on a regular basis to reflect changes in the state and health of ecosystems and their ability to provide services.

Just like the value of ecosystem services are not evenly distributed across the country, neither are the forces that drive the degradation of these ecosystems. Many of the ecosystem services provided, as well as the drivers of degradation are linked to the underlying biome, of which 12 main types are recognised in Namibia. Namibia's biomes are not evenly distributed across the different land tenures types within the country. Some land-tenure types contain entire biomes (such as Succulent Karoo within Protected Areas) and others like the Northern Kalahari woodlands are found in all tenure types (Table 7.1). NNF (2016) outlined the major threats and pressures to each set of ecosystem services within each biome. Each different biome is not only subject to threats that are a result of the sensitivity of their unique vegetation types and animal population, but also a result of their proximity to populations and history of use and accessibility. This spatial appreciation of the distribution of biomes within different land tenure types is important as the

Table 7.1 Distribution of Biome types used for the preliminary ecosystem service inventory by NNF 2016 among different land tenures. √√ = majority of biome within this land tenure, √ = only a small amount within land tenure type

Biome from NNF 2016	Freehold land	Communal land	Protected Areas
North-eastern rivers		√√	√
Northern Kalahari woodland	√	√√	√
Dry Kalahari woodland	√√	√	
Highland Acacia savanna	√√		
Karstveld	√√		√
Etosha pans and shrubland		√	√√
Cuvelai drainage		√√	
Western highlands	√	√√	
Nama Karoo shrubland	√√	√	
Northern Namib		√	√√
Namib sand sea			√√
Succulent Karoo			√√

protection of some unique ecosystem types (and the services they provide) will have to rely on conservation measures directed at specific types of land-use.

The main threats identified by NNF (2016) that were affecting biomes within each different land tenure types are outlined in Table 7.2. The two major degrading processes that are affecting ecosystems and their ecosystem services consistently in Namibia are overgrazing and bush encroachment. Over exploitation of resources was also identified as being important in many areas across Namibia.

Table 7.2 Main threats to the dominant biomes within each of the different land tenure types as set out in the preliminary ecosystem service inventory NNF 2016

Freehold land	Communal land	Protected Areas
Overgrazing	Over-grazing	Over-grazing
Over-abstraction of groundwater	Over-abstraction of groundwater	Off-road driving
Bush encroachment	Bush encroachment	Poaching
Fires	Fires	Mining
	Over-harvesting of natural resources	Over-harvesting of natural resources
	Clearing of land	

7.1 Overgrazing

Fodder production is an important and highly valuable ecosystem service in Namibia. The cost of losing the fodder-based industries in Namibia would total almost N$4 billion annually. The cost of physically replacing the fodder is much higher, however it is unlikely that the industry would continue if the service of fodder production was not provided. In many areas of the country, grazing already exceeds the estimated carrying capacity. Overgrazing affects a number of other ecosystem services, not only the production of future fodder. Over a third of the current fodder value is in areas that are considered overgrazed (grazing intensity>carrying capacity). This indicates that if these areas were better managed it is possible greater value could be achieved. This value is however also variable between years and dependent upon good rainfall. There is therefore risk in maximising output in any given year, as following years may not be able to support the same herd size as previous years.

Overgrazing (by cattle) reduces the amount of fodder available for game species. It is important to realise that the value of both these services cannot be maximised simultaneously. As such, overgrazing leads to lower carrying capacity of the veld, which in turn reduces the carrying capacity for game species. An optimum balance between the two can however be established when farming a combination of grazing and browsing species (wild or domestic) stocked at or below carrying capacities.

Poor rangeland management activities such as overgrazing can determinately affect a number of other regulating services such as groundwater recharge, sediment retention, water quality amelioration and flood attenuation. Loss of vegetation cover leads to increased surface run-off with less water being infiltrated to recharge groundwater aquifers.

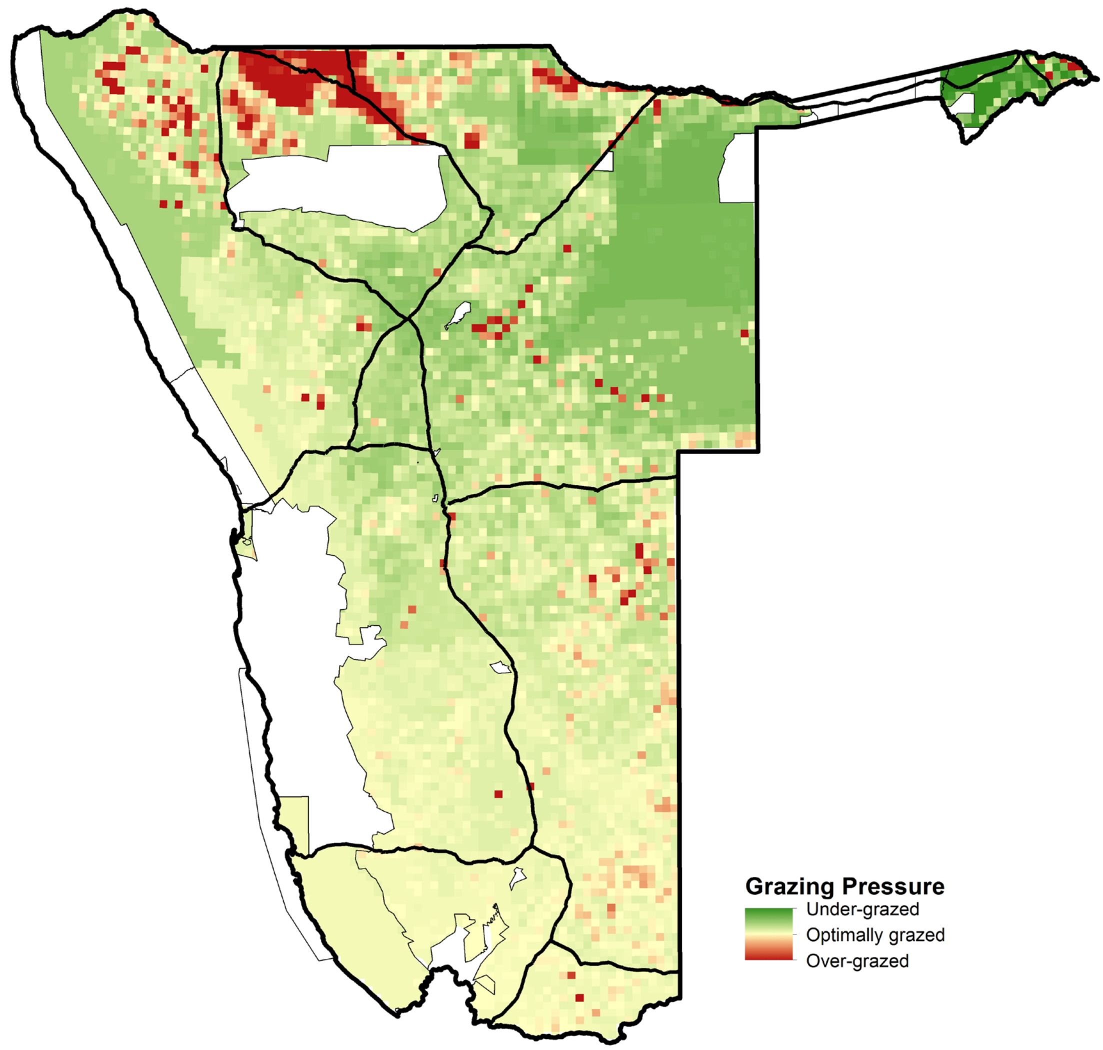
However, the current demand for groundwater resources in the areas of Namibia that are overgrazed is not substantial.

The loss of perennial grasses through overgrazing can also lead to increased erosion as the vegetation no longer intercepts the rainfall droplets (decreasing their erosivity) but also decreases the ability of the landscape to filter and retain sediments already being transported by surface run-off. In the northern communal lands severe overgrazing has led to the loss of grass cover which has exacerbated erosion. This added erosion can decrease the storage potential of seasonal Oshanas and increase local flooding.

Loss of grass cover also decreases the filtration ability of the landscape to deal with nutrients in surface run-off. This can lead to decreased water quality in rivers and streams. Additionally, overgrazing in wetland areas and flood plains along the perennial rivers in the north also likely impacts the ability of these wetlands to improve water quality, leading to a

loss of the service for downstream users. This is likely biggest problem along the banks of the Okavango River where grazing pressure is high. The estimated distribution of overgrazing within Namibia is shown in Figure 7.1.

Figure 7.1 Distribution of possible overgrazing in Namibia based on estimated carrying capacity and livestock density



7.2 Bush encroachment

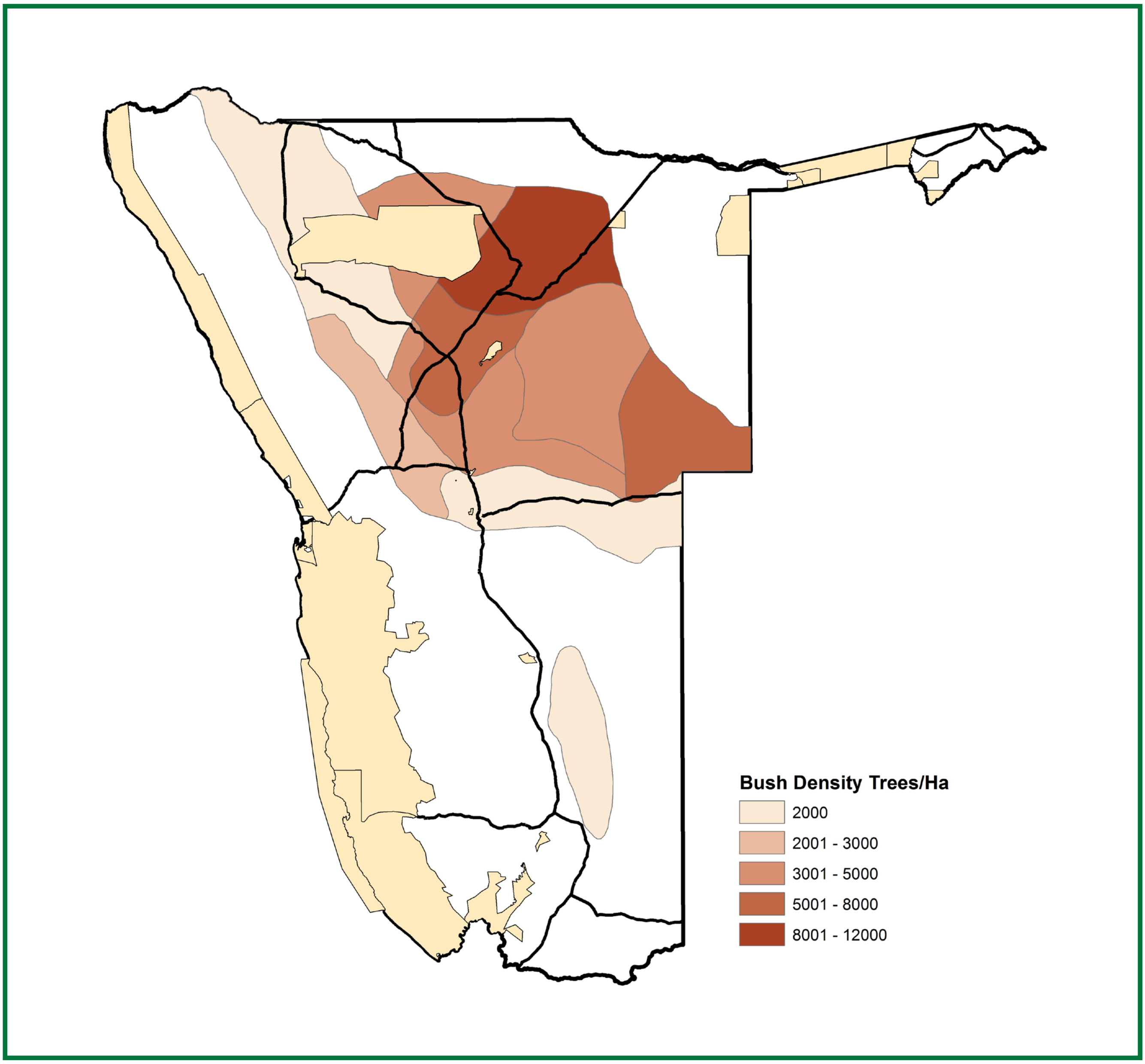
Many of the generic effects of bush encroachment on ecosystems and the provisioning of ecosystem goods and services are outlined in Box 5.1. In general bush encroachment has the potential to decrease the availability of some provisioning resources, but also has the potential to increase the provision of others, such as woody resources.

Bush encroachment in Namibia occurs mainly in the north-central freehold areas (Figure 7.2). The effect of bush encroachment on the harvesting of terrestrial resources within Namibia is likely not significant given that most areas affected by bush encroachment occur on freehold land where the demand for such services is limited. The biggest effect of bush encroachment in terms of ecosystem services within Namibia is likely through the lowering of carrying

capacity for grazing as well as the decrease in the rate of groundwater recharge (Stafford et al. 2017). Both of these affect freehold land much more so than they do communal land.

In addition, it is likely that bush encroachment also has a significant effect on local biodiversity and wildlife. The quantification of this effect, as well as the quantification of the effect of bush encroachment on tourism value and the visual appeal of the landscape are areas which, moving forward, require significant research.

Figure 7.2 Distribution of bush encroachment and tree density throughout Namibia



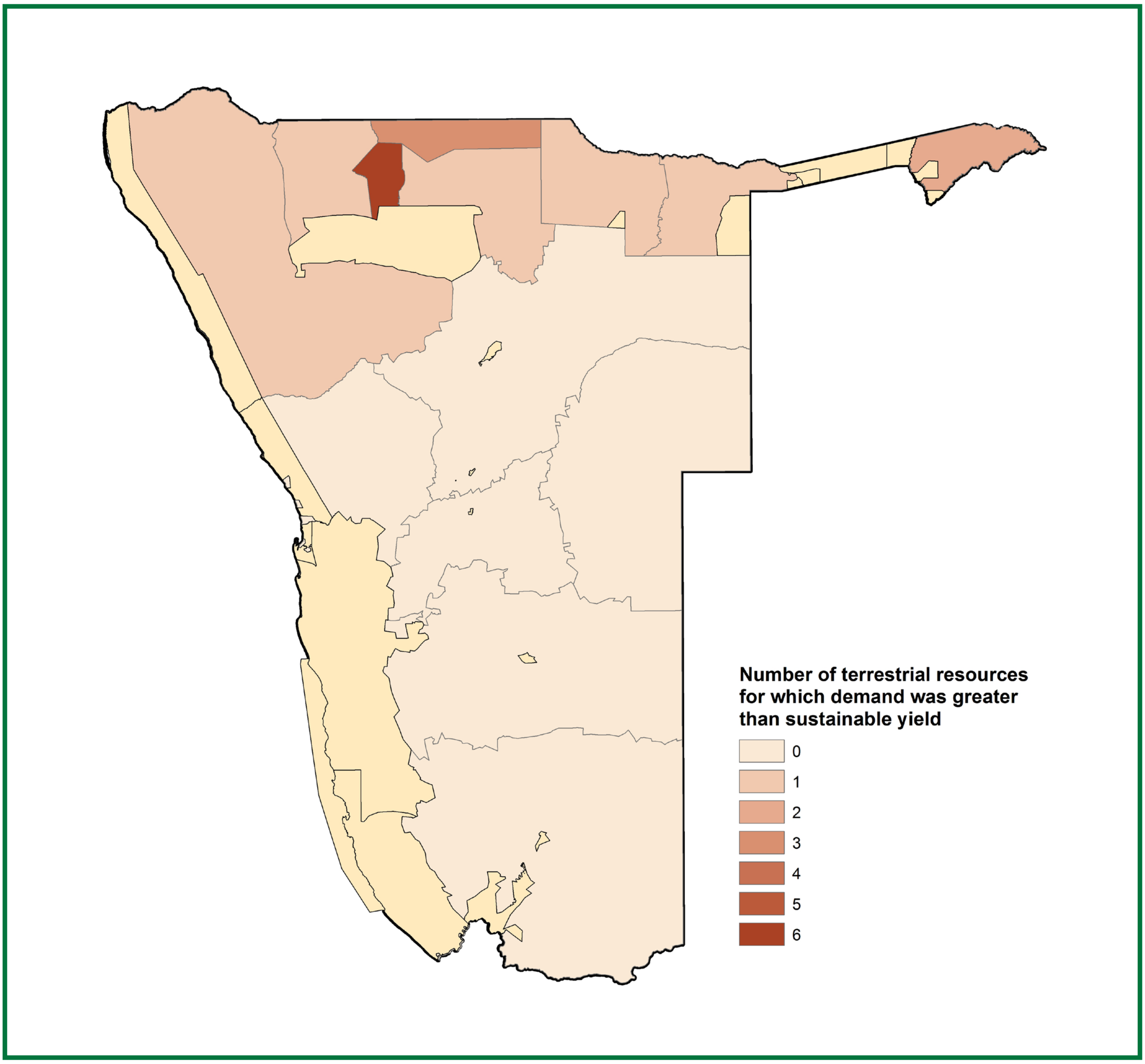
7.3 Overexploitation of natural resources

Resources provided by terrestrial ecosystems held a high value across the communal areas of Namibia. There were however many areas where the demand for such resources was far greater than the ability of the ecosystems to sustainably supply them. Figure 7.3 indicates the regions in which demand was greater than the sustainable yield for the terrestrial resources considered in this study. All the regions where this occurred were in the northern half of Namibia where population densities are highest. In these areas people are abstracting more than the ecosystem can sustainably

provide, meaning that these ecosystems are being actively degraded. As such, the value of resources in these regions, while high currently, will decline as the ecosystem becomes more degraded.

Areas where natural resources are heavily demanded tend to have a higher value. However, maintaining the balance between demand and sustainable use is difficult. The relationship between ecosystem service value and their demand unfortunately leads to degradation in most circumstances unless mechanisms are put in place to limit over-use. Further attention needs to be paid to mechanisms that can help ensure that resources, especially those that people depend on for their livelihoods, are not over-exploited.

Figure 7.3 Regions where the demand for natural resources was greater than the sustainable yield. The number of terrestrial resources for which this was the case is presented



8

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