PROJECT:

Proposed Encroacher Bush Biomass Power Project in Namibia (EIB Ref. Code: TA2015061 NA ITF): Vertebrate and Vegetation Baseline Study, Integration of all Biodiversity Components and Biodiversity Impact Assessment

African Wilderness Restoration

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Client	SLR Namibia	
Document history	Draft (date submitted)	Reviewed by
	V1-4: NA	Internal revisions
	V5: 15 May 2018	Werner Petrick (SLR)
	V5: July 2018	NamPower
	Version 6: submitted on 10 August	NamPower & ECC
Final	11 November 2019	
Document catalogue no.	AWR 2017-02.1	
Accompanying documents	Appendix 1: Woody species of conservation concern Appendix 2: Non-woody species of conservation concern Appendix 3: Other plant species of potential concern, which are not protected, endemic, near-endemic or Red Data species Appendix 4: Amphibian species expected at both sites Appendix 5: Reptile species expected at both sites Appendix 6: Mammal species expected at both sites Appendix 7: The effects of harvesting on community structure of selected savanna sites Appendix 8: Guidelines for complying with regulations governing bush thinning and value addition projects Appendix 9: Potential positive and negative environmental impacts of aftercare	
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Biodiversity provides the framework that supports life; without it we won't survive. Rational custodianship of nature is therefore a non-negotiable obligation.

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Acceptance[1] of report by client: Signature...	
Signed by	
On date	
On behalf of	
Of address	

[1] Acceptance means that AWR has fulfilled the Terms of Reference for the project to the client's satisfaction

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Acronym	Explanation
AWR	African Wilderness Restoration
CCF	Cheetah Conservation Foundation
CITES	Convention on International Trade in Endangered Species
DoF	Directorate of Forestry
ECC	Environmental Clearance Certificate
EHS	Environmental, Health and Safety Guidelines of the IFC
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EMP	Environmental Management Plan
EPL	Exploration and Prospecting Licence
FSC	Forest Stewardship Council
GIS	Geographical Information System
HES	Harvesting Effects Study
IBA	Important bird area
IFC	International Financial Corporation
IFC	International Finance Corporation
IUCN	International Union for the Conservation of Nature
LDN	Land Degradation Neutrality
MAWF	Ministry of Agriculture, Water and Forestry
NARIS	Namibian Agricultural Resources Information System
N-BIG	Namibia Biomass Interest Group
NBRI	National Botanical Research Institute
NBSAP	National Biodiversity Strategies and Action Plans
NRMPS	Namibia Rangeland Management Policy and Strategy
NUST	Namibia University of Science and Technology
PPAH	Pollution Prevention and Abatement Handbook of the World Bank
SFC	Structure, Function and Composition
SMART	Specific, measurable, achievable, relevant and time bound
SRTM	Shuttle Radar Topography Mission
UNCBD	United Nations Convention on Biological Diversity

A. Background

1 Introduction

Thicket formation, or bush encroachment, is a form of land degradation that is particularly prevalent in the semi-arid savannas of north-eastern and eastern Namibia. The high density of similar-aged stands of often multi-stemmed trees prevents the formation of a diverse and productive grass layer, decreases the groundwater re-charge rates and alters the species composition and function of the savanna ecosystem.

Such effects of encroachment are not merely of academic interest. Sustainable production of livestock and game on these extensive rangelands intimately depends on an intact, resilient and biologically diverse savanna ecosystem. By decreasing the structural and compositional heterogeneity and, through that, also negatively affecting functional processes such as nutrient flows, bush encroachment leads to significant negative effects on the potential for extensive animal production.

The need for corrective action through improved grazing management and through physical reduction of the woody biomass has long been recognised (see De Klerk 2004 and the various references therein). Appropriate management will not only improve the potential productivity of the rangelands but will also support a significant part of Namibia's biological diversity. Recently, an opportunity to use the abundant woody biomass as a resource for electricity generation arose when NamPower proposed to construct and operate a Project Site that will generate electricity through the combustion of encroacher bush acquired locally by sub-contractors (the *Proposed Encroacher Bush Biomass Power Project in Namibia*, hereafter Encroacher Bush Biomass Power Project (SLR 2017). In addition to electricity generation and decreased reliance on fossil fuel, other environmental benefits may also be realised simultaneously, including rangeland restoration resulting in increased productivity, increased soil water recharge rates and benefits for biodiversity through increased structural plant heterogeneity (SEA 2016; SLR 2017).

While the primary goal of the Biomass to Energy Project is to provide electricity through the sustainable harvesting of encroacher bush, an important secondary goal is the restoration of savanna rangeland productivity and associated ecosystem services through responsible bush harvesting. The latter goal is supported by several national-level development goals and international commitments under three multilateral agreements to which Namibia is a signatory, namely the climate, biodiversity and desertification conventions and is aligned with the environmental objective of the Forestry Stewardship Council (FSC) standards to ecologically restore land.

During a scoping phase for the Biomass to Energy Project, the broader economic, social and environmental (including biodiversity) costs and benefits of six potential sites across the country were weighed up against each other. Based largely on economic and social issues, a decision was made by NamPower to locate the Project Site at the Otjikoto substation outside Tsumeb, and the harvesting area then became a roughly 100 km radius surrounding this point. At a subsequent meeting, the harvesting area was enlarged to include some of the communal areas.

In principle, for the reasons listed above, the impacts that are caused by the Biomass to Energy Project are **expected to be predominantly positive for biodiversity** and there is therefore a bias for the project to go ahead. In total it is projected that about 12.8 % of the harvesting area will be harvested during the expected 25 year lifetime of the project (NamPower data).

Positive impacts are not a given, however. **Negative impacts could arise from two main sources**: 1) the Project Site itself, under the care and operation of NamPower, and 2) harvesting or bush clearing itself. Impacts related to the Project Site are relatively easy to define, they arise mostly at the point of construction and (with the exception of the impacts of powerlines) they have a relatively small footprint. With only one operator and clear responsibilities, they are also *relatively* easy to manage.

Negative impacts related to harvesting are however challenging. Although the encroached state is widely considered to be a degraded form of savanna, it still supports a number of specialised species, particularly invertebrates and birds that prefer thicket habitats. Some tree species that might be viewed as encroaching or might be difficult to distinguish from true invasive species during harvesting, are also of national conservation importance. Over-clearing and poor distinction between species could thus have definite negative impacts on species and populations.

Additionally, achieving the overarching ecological goal of the recovery of a resilient and productive savanna depends critically on good management and monitoring. Since it is foreseen that harvesting will be a privately-run component, with fuel suppliers supplying harvested biomass from various source points within a large area surrounding the plant, there is a real risk that management could fail. The failure to achieve the positive outcome of savanna restoration is thus in itself a large potential negative impact that has to be mitigated. And, although encroachment has received its fair share of scientific attention, surprisingly few studies tested the underlying hypothesis that the removal of woody biomass will result in the ecological restoration of a "better" savanna (which we loosely define as more resilient, productive and diverse savannas), nor to test best practises to reach this goal.

To proceed with the proposed project, NamPower is required under Namibian legislation to obtain an Environmental Clearance Certificate (ECC), which requires, in turn, a comprehensive EIA process (SLR 2017). The ECC will apply to activities relating to the Project Site and overhead power line connecting the biomass power station with the existing power network as well as harvesting and associated activities.

While the EIA process as it was originally foreseen did not concern itself with the harvesting component directly, in view of the over-riding importance of impacts related to harvesting, SLR proposed to broaden the EIA study to also include activities associated with the harvesting, transportation and after-care of the biomass harvesting process (SLR 2017). Specifically, it now also addresses harvesting management guidance.

Considering the above, the current baseline and impact assessment report is a summary of several aspects. It is divided into three main parts, namely A) Background (this section), B) Baseline Study and C) the Impact Assessment.

- The **Background (Part A)** gives an overall introduction, states the limitations and assumptions and presents a disclaimer and summarises the legal environment and standards and guidelines that are available.
- The **Baseline Study (Part B)** comprises descriptions of the affected environment (geo-bio-physical), the methods used for the baseline study, results of the fieldwork and literature studies, and a comprehensive treatment of savanna ecology that is relevant to the current project. It ends with a discussion of the findings, integrating the findings of focussed invertebrate (Irish 2018) and bird (Scott & Scott 2018) studies to present a defensible map of the sensitivity of habitats in the harvesting area and defines critical knowledge gaps.
  - These baseline results are further informed by the results of a standalone study in which we assessed the impacts of harvesting on vegetation structure and selected other variables. This ***"harvesting effects" study*** was done to add to the meagre repertoire of critical research on the dynamic community-level effects of harvesting and as proof of concept for a future monitoring programme. We report on that in an **Appendix** to the current report (Appendix 7).
  - Findings from the vertebrate and plants studies are supported by species lists compiled in Appendices 1 to 6.
- **Part C** is a ***Biodiversity Impact Assessment*** that uses the information from the baseline and the harvesting effects study to define seven potential impacts and mitigation options for each. In this we focus separately on the footprint effect of the Project Site itself and the harvesting component.
  - In recognition of the overriding importance of appropriate management of the harvesting process and its aftermath for impact mitigation, the final part of the report comprises a set of recommendations for the structuring and implementation of an ***adaptive management system***, including a suggested ***governance structure***, a ***training outline*** and ***research*** and ***monitoring programmes***. It concludes with a set of Best Practice Principles and Guiding Principles for harvesting with ecological restoration objectives, which expands on the general guidelines provided by the Strategic Environmental Assessment of Large-Scale Bush Thinning and Value-Addition Activities in Namibia (SAIEA 2016) and the Forestry and Environmental Authorisations Process for Bush Harvesting Projects (Pallett & Tarr 2017).

2 Approach to Study

2.1 Terms of reference

The terms of reference for the specialized study on vertebrates (amphibians, reptiles and mammals) and vegetation assessment, as well as integration of these with other biodiversity components (i.e. invertebrates and birds) will cover construction, operation and decommissioning and closure phases where relevant and conceptual closure planning principles will be incorporated into the EIA and EMP reports.

- Refer to work conducted as part of the Scoping phase for the selected site (i.e. Otjikoto).
- Conduct a study of the available habitats on the selected site for the Project Site.

- Study the effects of harvesting on the biodiversity to provide information for the definition of long-term ecological goals and quantitative ecological targets for management of harvesting. Existing harvesting guidelines will be reviewed/studied and additional/amended management measures will be included in the EMP, as and where required.
- Establish whether there are any no go areas for biomass harvesting and refine sensitivity ratings for different vegetation types and habitats with increased focus on sensitive plant species, communities and habitats in the expanded harvesting area.
- Describe the selected Project Site in terms of location (about the environmental sensitivity of geographical areas likely to be affected); climate; topography; geology; soils and land capability; terrestrial vegetation; and terrestrial fauna.
- Describe the key ecological drivers and functions, and place all taxa within that context, incorporating the baseline information from the invertebrate study as well as the avifauna assessment.
- Assess the overall biodiversity impacts on the individual species as well as the ecosystem before and after mitigation.

2.2 Understanding and clarification of ToR

Although it goes without saying that the construction of the Otjikoto Power Station and associated infrastructure will have an impact on the biological diversity of the site itself and its adjacent environments, we believe that the largest and longest-lasting impact on biodiversity will occur through the harvesting activities. The guiding principles for harvesting, as well as the methods and management approach during and after harvesting will play the most important role in a) determining and mitigating the potential negative impacts on existing savanna structure, function and composition, and b) achieving the environmental, secondary goal of restoration of savanna function and productivity.

As such, AWR understood the ToR to look at direct impacts of the biomass Project Site on biodiversity, but to also consider general impacts on the ecological dynamics of the savannas as these relate to harvesting and transportation of the biomass. However, our assessment of this component is not area-specific but focuses rather on the general principles of the savanna ecosystem's dynamics. This approach aligns closely with existing harvesting guidelines.

2.3 Summary of impact assessment method

Table 1. Assessment method used in determining the significance of impacts.

*PART A: DEFINITION AND CRITERIA**		
Definition of SIGNIFICANCE		Significance = consequence x probability
Definition of CONSEQUENCE		Consequence is a function of severity, spatial extent and duration
Criteria for ranking of the SEVERITY/NATURE of environmental impacts	H	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action. Irreplaceable loss of resources.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints. Noticeable loss of resources.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints. Limited loss of resources.
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	L	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	L	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national

PART B: DETERMINING CONSEQUENCE					
			SEVERITY = L		
DURATION	Long term	H	Medium	Medium	Medium
	Medium term	M	Low	Low	Medium
	Short term	L	Low	Low	Medium
			SEVERITY = M		
DURATION	Long term	H	Medium	High	High
	Medium term	M	Medium	Medium	High
	Short term	L	Low	Medium	Medium
			SEVERITY = H		
DURATION	Long term	H	High	High	High
	Medium term	M	Medium	Medium	High
	Short term	L	Medium	Medium	High
			L	M	H
			Localised Within site boundary Site	Fairly widespread Beyond site boundary Local	Widespread Far beyond site boundary Regional/ national
			SPATIAL SCALE		

PART C: DETERMINING SIGNIFICANCE					
PROBABILITY (of exposure to impacts)	Definite/ Continuous	H	Medium	Medium	High
	Possible/ frequent	M	Medium	Medium	High
	Unlikely/ seldom	L	Low	Low	Medium
			L	M	H
			CONSEQUENCE		

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	**Decision guideline**
High	It would influence the decision regardless of any possible mitigation.
Medium	It should have an influence on the decision unless it is mitigated.
Low	It will not have an influence on the decision.

*H = high, M= medium and L= low and + denotes a positive impact.

3 Limitations and Assumptions

1. The fieldwork during the assessment phase was limited to relatively short visits to the proposed Project Site and proposed harvesting area. Because of the large size involved, only a small fraction of the total harvesting area could be visited. As always with ecological studies, the observation period is critical – short periods of observation and measurement lead to more uncertainty, because more of the conclusions must be based on generalisations about the ecosystem obtained from literature studies. An important outcome of this situation (and a key point that we want to make in the report) is that, apart from specific knowledge gaps, there is still a clear need for intensive monitoring of savanna dynamics under various harvesting and post-care scenarios to determine long-term outcomes and to inform careful, adaptive and pre-emptive management. Throughout we have also tried to be clear where uncertainties may affect the overall interpretation of results.
2. The data sources available on the distribution range of species may not reflect actual ranges accurately. For example, new data gathered through the citizen science project of the Environmental Information System, has discovered snake species occurring outside the known distribution range. This is certainly also true for other taxa than reptiles.
3. The assessment of potential impacts to biodiversity is essentially an evaluation of the risk that individuals, populations, habitats or processes will be affected in such a way that their persistence in the region (or, in the worst cases, globally) is threatened. A key input into this risk assessment is knowledge of the species, their ecology and their dynamics – based on these aspects, the significance of the impact and the most appropriate mitigations are determined. The better these aspects are known, the easier it is to obtain a confident estimate of the risk that certain actions or developments can cause harm. Often, however, the biology and ecology of a species are poorly known, simply because the species has not been studied that well in the past or because it is particularly rare or sparsely distributed and therefore seldom encountered. Similarly, knowledge about ecological processes (such as dispersal routes, interactions of species with their predators, even ecosystem-level processes such as nutrient cycling) is lacking for many of Namibia's natural systems because these kinds of studies require specialist capacity that has not existed in the past. As a result, some generalisations must be made about expected responses in the proposed harvesting area from studies conducted in other savanna types, e.g. southern Kalahari savannas.

4 Disclaimer

Ecological baseline studies are invariably too short and too small to provide confident evidence of species presence, abundance, distribution or dynamics, or of their relations to environmental variables (see also previous section) on the scale that conclusions are drawn or management actions are recommended. This is even more relevant in the current study because of the sheer size of the area. Although we have attempted to make as much use of the time we could spend on fieldwork, and although we partially tried to rectify the low confidence by doing a preliminary study on the effects of previous harvesting initiatives on biodiversity variables, the current study and its conclusions rely to a large extent on published results and reviews by other researchers.

As such, while we have strong confidence in our interpretations of previously published and current studies' results as well as in the recommendations we make on their basis, we wish to point out to the reader that these should be viewed with healthy scientific scepticism considering the relatively thin statistical inference layer on which it is all based. In addition, the geographic scale of the current study means that recommendations are based on broad ecological generalisations, each of which might be inapplicable to varying degrees in specific situations at a local scale.

We therefore cannot accept liability for outcomes of management actions based on our findings or our recommendations where these were applied without due recognition of the specific biological, climatic and geographic context and appropriate integration of uncertainties that arise from natural variability.

5 Legislative context

5.1 Applicable laws and policies

Table 2. List of acts and policies and their relevant aims and requirements related to the harvesting of bush for energy production.

	Act, policy or convention	Aims and requirements
1	The Constitution of the Republic of Namibia	Any activities must comply with Section 95(l), which provides for "the maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilisation of living natural resources on a sustainable basis ..."
2	The Public Health Act 36 of 1919	Prohibits users of land to cause nuisances that may be injurious or dangerous to health. The definition of 'nuisance' includes the emission of environmental pollutants.
3	Draft Pollution Control and Waste Management Bill of 1999	Provides for the control and management of several types of pollution, inter alia to reduce their effects on species; until the bill is enacted, the draft bill serves as guideline for the design of future compliance.
4	Environmental Management and Assessment Act of 2007	This act provides a set of principles for environmental management and lists those activities that require an EIA process (this includes all types of mining and exploration activities). The implementation guidelines are given in the associated Regulations of 2012.
5	Nature Conservation Ordinance 4 of 1975, as amended in 1996	Provides for the declaration of protected areas and for the specific protection of scheduled species where they occur.
6	Inland Fisheries Resources Act 1 of 2003	Provides for the protection of aquatic ecosystems and applies to any freshwater body that is not situated on private property. 'Fish' is defined to include freshwater crustaceans. Section 20 prohibits the erection or installation of any structure in a river or stream in the absence of consultation with the Minister.
7	Forest Act 12 of 2001, as amended in 2005	Aims to conserve soil and water resources, maintain biological diversity and to use forest produce in a way which is compatible with the forest's primary role as the protector and enhancer of the natural environment.
8	United Nations Convention on Biological Diversity (UNCBD)	Aims to pursue the conservation of biological diversity and the sustainable use of its components. Participating countries are expected to introduce appropriate procedures requiring environmental impact assessment of projects that are likely to have significant adverse effects on biological diversity, with a view to avoiding or minimizing such effects. Also explicitly provides an opportunity for a more positive approach to be taken in impact assessments, to identify opportunities for enhancing biodiversity. The objectives of the UNCBD correspond closely with Article 95 of the Constitution, as they seek to promote: 1. The conservation of biological diversity; 2. The sustainable use of its components; and 3. The equitable sharing of benefits arising out of the utilization of genetic resources.

	Act, policy or convention	Aims and requirements
9	National Biodiversity Strategy and Action Plan 1 and 2 (draft)	The NBSAP is the key national level implementing instrument of the objectives of the United Nations Convention on Biological Diversity (UNCBD) (so-called Aichi Targets). Objectives are to: 1. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society; 2. Reduce direct pressures on biodiversity and promote the sustainable use of biological resources; 3. Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity and enhancing the benefits to local communities; and 4. Enhance implementation of NBSAP through participatory planning, knowledge management and capacity building Key aspects relevant to BIA studies relate to all objectives, but particularly 1.4, 2.1, 2.4, 3.2, 3.4, 3.5 and 4.3.
10	The Convention on International Trade in Endangered Species (CITES) of 1973	Regulates trade in endangered species, through listing in appendices: • Appendix I includes species threatened with global extinction, and trade in these is subject to particularly strict regulations. It is only authorized under exceptional circumstances. • Appendix II includes species that are not necessarily now threatened with extinction but may become so unless trade in them is strictly regulated to avoid utilization incompatible with their survival. It also includes any other species for which trade needs to be regulated in order to effectively control trade in strict Appendix II species. • Appendix III includes species where trade regulation to prevent exploitation is mainly needed on the individual country or regional level. Namibia currently has no CITES Appendix III species.
11	Convention to Combat Desertification	Aims to prevent excessive land degradation that may threaten livelihoods.
12	National Rangeland Management Policy and Strategy of 2012	Aims to enable farmers to manage their rangeland resources so that animal production per hectare is sustainably improved, vulnerability to a highly variable resource base is decreased, and biodiversity is improved and maintained (continue providing essential ecosystem services). To achieve these aims, it advises that emphasis should be placed on: • Improving the nutrient cycle through promotion of plant diversity, healthy soil structure and functioning ecosystems, • Improving the water cycle through good soil cover and aeration; sufficient soil organic matter; reduced competition for soil moisture by undesirable bushes (i.e. bush thinning); and restoration of eroded land to reduce runoff, and • Improving and maintaining the biodiversity of rangelands through correct intensity of plant utilisation; adequate recovery of utilised plants (frequency of utilisation); reclamation of denuded rangelands; erosion control; use of biodiversity-friendly parasite control; and managing rangelands for heterogeneity rather than for homogeneity.
13	National Agriculture Policy (2015)	Recognises the problems of bush encroachment, desertification and environmental degradation caused by the destruction of forest cover, soil erosion, overgrazing and bush encroachment. Aims to "establish mechanisms to support farmers in combating bush encroachment effectively over the short and long term".

5.2 Relevant standards to comply with

The first seven standards in Table 3 were prescribed by the project client. These include two of the EIB's own standards, two of the International Finance Corporation's (IFC's) standards, two World Bank standards and the Forestry Stewardship Council's (FSC®) standards.

There are two relevant Namibian standards. The first is summarised in a booklet published in 2017 by the Ministry of Agriculture, Water and Forestry together with the Ministry of Environment and Tourism, called the "*Forestry and Environmental Authorisations Process for Bush Harvesting Projects*" (Pallet & Tarr 2017). This booklet explains the Namibian environmental laws and regulations that must be complied with in bush harvesting and value addition projects and defines a generic Environmental Management Plan (EMP) which includes a number of guidelines designed to allow the industry to balance the sometimes competing objectives of productivity and conservation. The second, called "*Harvesting of Encroacher Bush: Compendium of harvesting technologies for encroacher bush in Namibia*", is a similar guideline, focusing on the actual process of harvesting and including a definition of best practice in terms of certain aspects of environmental management.

Both Namibian standards referred to above make reference to the FSC® and alignment thereof as it provides guidelines on sustainable use of Forestry resources. There are currently two certification bodies that operate in Namibia, both of which have a Namibian adapted based FSC® standard to which Forest Management (FM) units must comply with in order to achieve certification. FSC® principles are beneficial to the resource, and FSC certification has been proven to be economically more profitable, as products can achieve higher prices on the export market.

Table 3. List of standards and their relevant aims and requirements related to the harvesting of bush for energy production. Namibian-specific standards are highlighted in bold.

	Standard	Aims and requirements
1	EIB's Statement of Environmental and Social Principles and Standards (2009)[2]	Outlines the standards that the Bank requires of the projects that it finances, and the responsibilities of the various parties. Focuses particularly on climate change, biodiversity and the social dimensions of sustainable development.
2	EIB's Environmental and Social Practices Handbook (2013)[3]	Part I describes the standards to achieve (across 10 thematic areas covering the full scope of environmental, climate and social impacts and issues). Part II describes the internal environmental and social due diligence processes and practices of the Bank. The aim is to ensure that all financing activities are consistent with its environmental and social standards.
3	International Finance Corporation's (IFC's) Performance Standards on Environmental and Social Sustainability[4]	IFC's Environmental and Social Performance Standards define clients' responsibilities for managing their environmental and social risks across eight thematic areas.

[2] http://www.eib.org/infocentre/publications/all/environmental-and-social-principles-and-standards.htm

[3] http://www.eib.org/attachments/strategies/environmental_and_social_practices_handbook_en.pdf

[4] https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Policies-Standards/Performance-Standards

	Standard	Aims and requirements
4	IFC Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources (2012)	PS 6 is of relevance to the current study: PS6 recognizes that protecting and conserving biodiversity, maintaining ecosystem services, and managing living natural resources adequately are fundamental to sustainable development. As such it requires projects financed by member institutions to adhere to a range of criteria related to the sustainably management and mitigation of impacts on biodiversity and ecosystem services throughout the project's lifecycle. It includes a requirement to consider the differing values attached to biodiversity and ecosystem services by affected communities and other stakeholders.
5	IFC's Environmental, Health and Safety (EHS) Guidelines[5]	These are technical reference documents with general and industry-specific examples of Good International Industry Practice (as defined in PS3: *Resource Efficiency and Pollution Prevention*), used as a technical source of information during project appraisal activities. These Guidelines contain the performance levels and measures that are normally acceptable to IFC, and that are generally considered to be achievable in new facilities at reasonable costs by existing technology.
6	World Bank's Pollution Prevention and Abatement Handbook (PPAH)[6]	This Handbook covers almost 40 industrial sectors and represents state-of-the-art thinking on how to reduce pollution emissions from the production process. Consists of three sections: Part I, aimed primarily at government decision-makers, is a summary of practice-based key policy lessons in pollution management. Part II presents good-practice notes on implementation of policy objectives. Part III provides detailed guidelines to be applied in the preparation of World Bank Group projects.
7	Forestry Stewardship Council Certification Standards[7]	A voluntary global forest certification system established for forests and forest products to promote better forest management. It has 10 Principles and associated Criteria that form the basis for all FSC forest management standards and certification. These criteria and standards range across a broad spectrum of thematic areas that are involved in the sustainable utilisation of forest products, from strictly environmental to social and economic and the recognition of indigenous people's rights.
8	World Bank Operational Directives and Guidelines (ODG)[8]	Contains operational policies, directives, procedures and other instructions to staff that apply to Bank operations.
9	Forestry and Environmental Authorisations Process for Bush Harvesting Projects (MAWF 2017)	The Ministry of Agriculture, Water and Forestry, together with the Ministry of Environment and Tourism published this booklet, which explains the Namibian environmental laws and regulations that must be complied with in bush harvesting and value addition projects and defines a generic Environmental Management Plan (EMP) for harvesting operations.
10	Harvesting of Encroacher Bush: Compendium of harvesting technologies for encroacher bush in Namibia (MAWF 2015)	Provides practical methods and defines best-practice in terms of environmental management during encroacher bush harvesting

[5] https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/policies-standards/ehs-guidelines

[6] https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/publications/publications_handbook_ppah__wci__1319577543003

[7] https://ic.fsc.org/en/what-is-fsc

[8] https://policies.worldbank.org/sites/ppf3/Pages/Manuals/Operational%20Manual.aspx

	Standard	Aims and requirements
11	Equator Principles[9]	A risk management framework adopted by financial institutions, for determining, assessing and managing environmental and social risk in projects; primarily intended to provide a minimum standard for due diligence and monitoring to support responsible risk decision-making. Its wide acceptance by member institutions means that it has significant influence over environmental standards for the implementation of development projects. The IFC's performance standards are justified by the EPs. Detail is too much to go into here, please refer to website for more information.

B. Baseline Study

VI. Methodology

6.1 Literature and existing data review

6.1.1 Plants

Relevant existing information was reviewed, including literature sources (e.g. Giess 1998, Hilliard 1994, Klaassen & Craven 2003) and known plant species distribution as well as species and area conservation status. No field guides are available for this area.

Species lists for the quarter-degree squares included in the study area were obtained from the National Herbarium (2011) and the Namibian Tree Atlas Project and consulted to see what species of conservation concern have previously been recorded in those squares. An annotated list of species of concern was compiled for the four different vegetation zones to try and assess their sensitivity to large-scale clearing and to try to make useful management recommendations.

Nomenclature and species conservation status largely follows Klaassen & Kwembeya (2013), although Craven (2002) and Craven & Vorster (2006) were consulted on endemic occurrence.

Red Data Status follows Klaassen & Kwembeya (2013) except for species that have been reassessed by the Red Data officer at the NBRI (S. Loots) since that publication. Protected status of woody species follows the new list gazetted by the Directorate of Forestry (Government Gazette No. 5801).

6.1.2 Amphibian, reptile and mammal databases

The Atlas of Namibia GIS database (Mendelsohn et al. 2002) includes spatial data on the expected species richness and number of endemic species for taxa including plants, scorpions, reptiles, amphibians, birds and mammals. The species richness and number of potential endemic species were extracted for the study area from the Atlas of Namibia GIS database (Mendelsohn et al. 2002) in a GIS.

The IUCN has comprehensive spatial databases for mammals and amphibians. The most recent respective databases (2017.3) were downloaded on 15 March 2018. In a GIS, the mammal and

[9] http://equator-principles.com/about/

amphibian species with geographic distributions overlapping a 1 km buffer created for the Project Site and the extended harvesting area, respectively, were extracted.

For reptiles, the potential occurrence of species at sites and the harvesting area was estimated from the distribution ranges provided in Branch (1998) for non-snakes and Marais (2004) for snakes. The IUCN reptile database is not comprehensive and covers only a subsample of the actual diversity (about 10-20% of potential species).

The conservation and legal status of amphibians, reptiles and mammals are according to the Namibia Biodiversity Database (http://biodiversity.org.na), downloaded on 15 March 2018. Data on endemism are according to Griffin (2003).

6.1.3 Other databases

Climatic data such as mean annual temperature and frost days per year were also extracted for the study area from the Atlas of Namibia database. The WorldClim (www.worldclim.org) long-term mean rainfall was used to extract rainfall for the study site and associated harvesting area (Fick & Hijmans 2017). WorldClim is a set of global climate layers (gridded climate data) with a spatial resolution of approximately 1 km^2.

According to the Forestry and Environmental Authorisations Process for Bush Harvesting Projects (Pallett & Tarr 2017), no bush harvesting should take place on slopes steeper than 12% (i.e. 1 in 8) and harvesting is not recommended on slopes between 5-12%. Slope categories for the study area were calculated from the Shuttle Radar Topography Mission (SRTM) 1 Arc-Second (approximately 30m spatial resolution) data distributed by the United States Geological Survey data portal using Spatial Analyst in ArcGIS for the harvesting area.

The whereabouts of state protected areas and infrastructure such as the veterinary cordon fence were sourced from the Namibia Spatial Agency's spatial database, the NARIS (Ministry of Agriculture, Water and Forestry) and Atlas of Namibia spatial data repositories.

6.1.4 Integrating other specialist studies' results

Two other biodiversity specialists were involved in the project: John Irish did a baseline study of invertebrates (Irish 2018) and Mike and Ann Scott did the same for birds (Scott & Scott 2018). SLR prepared a report on the soils of the harvesting area (SLR 2018). We read their reports and integrated their findings into our overall review of savanna dynamics but principally we include it as part of our Discussion (Section 8). In this regard we paid specific attention to their assessment of habitat or taxon sensitivities (Sections 7.10 and 8.2).

6.2 Determining sensitivity for the taxa of the current study

6.2.1 Plants

The zones, and in the case of the Karstveld, various habitats, were assessed for sensitivity according to the following criteria:

- Density of species of conservation concern (protected, endemic, threatened, red data).
- Presence of species not protected at the moment but whose present conservation status may be seriously compromised by large scale harvesting.
- Presence of many large trees.

- Difficulty/ease of management of impacts.
- Recovery potential, taking soils and growth rate of prevalent species of concern into account.
- Historic impacts.

6.2.2 Vertebrates (excluding avifauna)

We considered it impractical to distinguish habitats separately for amphibian, reptile and mammal species, because of the large range of niche requirements across such a diverse group of organisms ranging in body mass from a few grams to a few tons. For instance, while rhinos will not distinguish between riverine fringe and thornveld, some reptile species may. However, drawing different maps for every group is impractical and of little use from a management perspective. We therefore considered the vegetation zones to be a practical and adequate basis for management purposes. The zones' sensitivity was rated according to the probability that species of conservation importance as well as endemic species could occur there, and whether harvesting activities could impact on local populations in a manner that precluded mitigation actions. The general species richness and endemicity patterns were also considered and additional sensitivity zones (e.g. omiramba and other drainage lines) were integrated into a map depicting sensitivity of all taxa.

6.3 Habitats

Deciding on a unified habitat map across widely different taxa such as sessile plants, mobile and highly mobile vertebrates and invertebrates is usually a complex and ultimately fruitless challenge, especially across the large harvesting area. In practice, the most logical approach is to use the variation in vegetation structure and composition together with landform to classify the area into biological zones, which we for the sake of simplicity here call habitats.

Our approach is inherently ecological, and aims to capture ecological properties rather than management categories such as prescribed by the International Finance Corporation's Performance Standard 6 (IFC PS6;

Table 4). To meet the requirements of IFC PS6, we additionally divided the habitats into modified, natural and critical categories. These definitions were based on the characteristics of each as defined by the IFC's PS6 (

Table 4).

Table 4. Categorisation of habitats according to IFC PS6 (see Table 3 for references).

	Habitat Category	Characteristics	Prescribed action
1	Modified	Areas where there has been apparent alteration of the natural habitat, often with the introduction of alien species of plants and animals or where the species composition has been significantly altered	Exercise care to minimize any conversion or degradation of such habitat. Depending on the nature and scale of the project, identify opportunities to enhance habitat and protect and conserve biodiversity as part of operations.
2	Natural	Land and water areas where the biological communities are formed largely by native plant and animal species, and where human activity has not essentially modified the area's primary ecological functions	[Do] not significantly convert or degrade such habitat, unless: • There are no technically and financially feasible alternatives • The overall benefits of the project outweigh the costs, including those to the environment and biodiversity • Any conversion or degradation is appropriately mitigated Mitigation measures will be designed to achieve no net loss of biodiversity where feasible, and may include: • Post-operation restoration of habitats • Offset of losses through the creation of ecologically comparable area(s) that is managed for biodiversity • Compensation to direct users of biodiversity
3	Critical	Critical habitat is a subset of both natural and modified habitat that deserves particular attention. Critical habitat includes: • areas with high biodiversity value, including habitat required for the survival of critically endangered or endangered species; • areas having special significance for endemic or restricted-range species; • sites that are critical for the survival of migratory species; areas supporting globally significant concentrations or numbers of individuals of congregatory species; • areas with unique assemblages of species or which are associated with key evolutionary processes or provide key ecosystem services; • and areas having biodiversity of significant social, economic or cultural importance to local communities.	[Do] not implement any project activities unless: • There are no measurable adverse impacts on the ability of the critical habitat to support the established population of species described in [the previous column] or the functions of the critical habitat described in [the previous column]; • There is no reduction in the population of any recognized critically endangered or endangered species; • Any lesser impacts are mitigated [similar to that described for Natural Habitat]

6.4 Fieldwork

Two fieldwork sessions were done. First, two of us (T. Wassenaar ([TW] and C. Mannheimer [CM]) visited the Project Site, and also did a survey of the harvesting area as it was originally defined (a 100 km radius around the plant site) from 28 to 30 August 2017. Various routes were driven, in different directions to try to establish the extent of the zones and potential problem areas.

From 19 to 22 December 2017 and 7, 8, 13, 14 and 17 January 2018, the expanded harvesting area was again visited by the botanical specialist alone (CM), but in more detail and with a focus on the vegetation.

Before this, during the fieldwork for the scoping study, TW and C. van der Waal, together with T. Shuuya (TS) and O. Freyer (OF), visited the study area to plan for a study to assess the effects of harvesting on a range of taxa and ecological characteristics of vegetation and vertebrate communities. This 'harvesting effects study' was done by TS, OF and E. Ngahlipo on Farm Tirol, Farm Gabus and the Cheetah Conservation Fund (CCF) farms (Appendix 7).

7 Description of the affected environment's biophysical properties and geography

The current study's brief focuses on both the site chosen for the Project Site itself (Project Site) and the harvesting area surrounding it. At about 44 ha, the Project Site is an order of magnitude smaller than the ~47,700 km^2 harvesting area (although only a fraction of it will eventually be impacted), and we expect far fewer issues in terms of biodiversity impacts than for the whole harvesting area. In addition, the Project Site is for all intents and purposes simply a small example of the habitats encountered in the harvesting area and contains species that are found over the larger area as well.

7.1 Geography

The proposed **Project Site** is located about 7 km west of Tsumeb, across the road from the existing Otjikoto substation (Figure 1). The main biophysical characteristics, climate, land use, ecological drivers and perceived impact regimes for the plant site was summarised in the Scoping Report. In brief, the site is on level karst covered with a shallow to medium sandy substrate forming mainly petric calcisols (SLR 2018). Vegetation density is high, with moderate evidence of encroachment.

The proposed **harvesting area** was taken as a zone of about 100km radius around the Project Site, enlarged to the south to accommodate more of the encroached savannas in that region, and to the east to include some of the non-title deed communal areas (Figure 2). Land use is dominated by commercial farming, with minor areas in the east and north falling in communal areas and a section in the west falling in the Etosha National Park (Figure 2). In the south, the harvesting area overlaps with a small part of the Waterberg Plateau Park. Although the protected areas will sometimes feature in descriptions of ecology, they are excluded from the actual harvesting area.

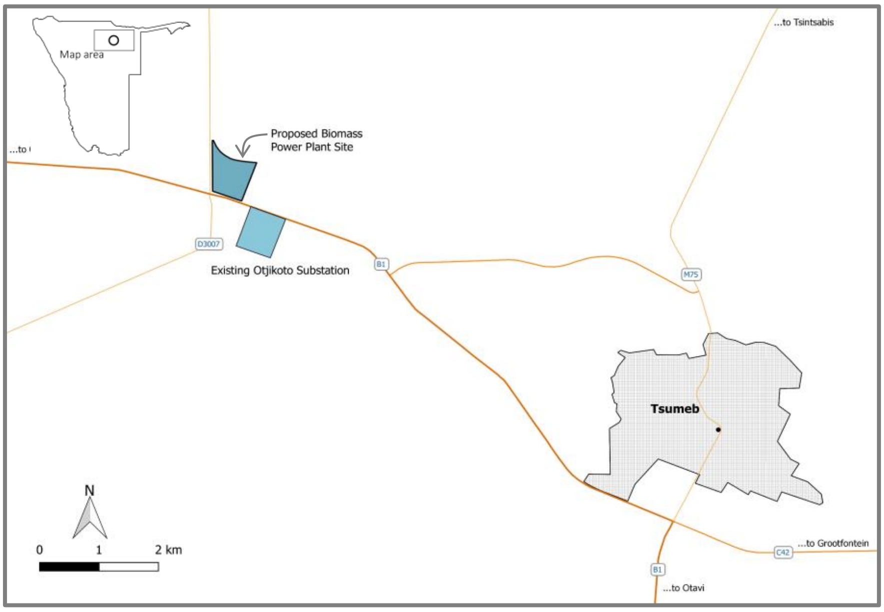

Figure 1. Location of the selected Project Site for the proposed Otjikoto biomass power plant west of Tsumeb.

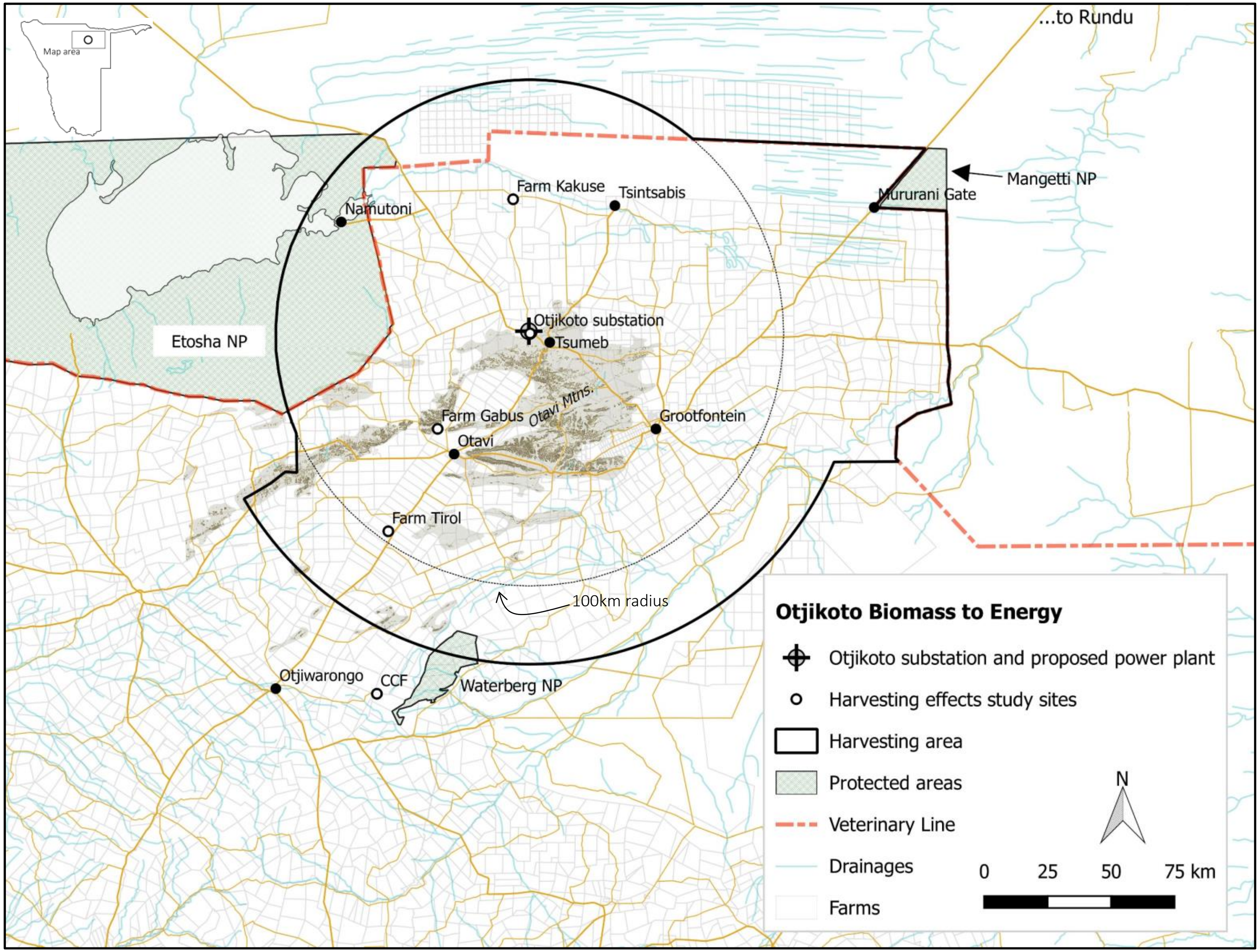

Figure 2. The study area including the proposed harvesting area and the location of the existing Otjikoto substation and proposed Project Site west of Tsumeb. Also indicated are the Otavi mountains, locations of places mentioned in the text and some basic orientation points. Light grey lines indicate the boundaries of commercial farms. CCF: Cheetah Conservation Fund

7.2 Geomorphology

Topographically the harvesting area is essentially a plain interrupted by the prominent limestone Otavi Mountains in the centre, which taper out in a spur that stretches for about 150 km to the southwest (Figure 2). In the south, the area overlaps the sandstone Waterberg massif, but only partially so (Figure 2). The geology of the harvesting area is dominated by sandy substrates of the Kalahari Group, followed by limestones and dolomites of the Otavi Group, schists and dolomites of the Swakop Group and sandstones and conglomerates of the Waterberg Basin (Figure 3). Two relatively metamorphic complexes make up the rest: the Grootfontein Complex and the Epupa, Huab and Abbabis Complex (Figure 3).

7.3 Soils

Three main soil groups are derived from three main parent material sources: shallow to deep Arenosols and Luvisols from sands of the Kalahari basin, shallow Calcisols and Leptosols from planed-down dolomite, limestone and schist of the plains landscapes and Cambisols from the Otavi Mountain limestones (SLR 2018; Figure 5A). The soil groups broadly follow the spatial distribution of their geological parent material and correlates at least partially with the vegetation zones (Figure 3; Figure 5).

7.4 Climate

Mean annual precipitation is a function of two main gradients: the national-scale decline in rainfall from northeast to southwest, and the orographic effect of the Otavi Mountains (Figure 4). The WorldClim modelled data suggest that the maximum rainfall in the harvesting area would occur on the Otavi Mountain itself (approximately 590 mm pa on average) and in the area to its north, while minimum rainfall (about 360 mm pa) will occur on the southern edge of the harvesting area (Figure 4).

7.5 Biomes

The harvesting area, of which the Karstveld forms a large part, is part of the Savanna Biome of Irish (1994) (Figure 6), where phanerophytes (woody perennials) and hemicryptophytes (perennials that die back in winter, such as grasses) are regarded as the dominant life forms, although in good rainy seasons therophytes (annuals) are also briefly abundant. This largely corresponds with the Tree-and-shrub Savanna Biome of Mendelsohn et al. (2002), who describe the vegetation type as mixed woodlands, with broadleaved woodland towards the north-east and Acacia woodland towards the south-east.

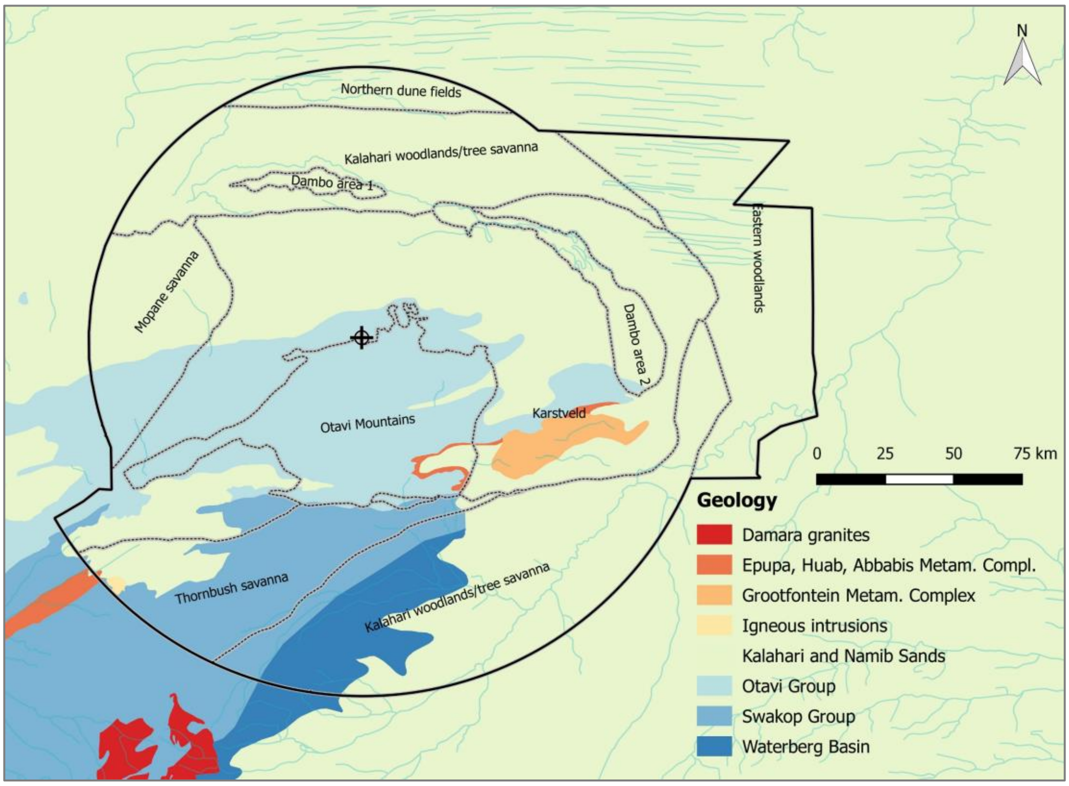

Figure 3. Geology of the study area, overlain with the vegetation types as defined during the current study (see below). Source: Geological Map of Namibia.

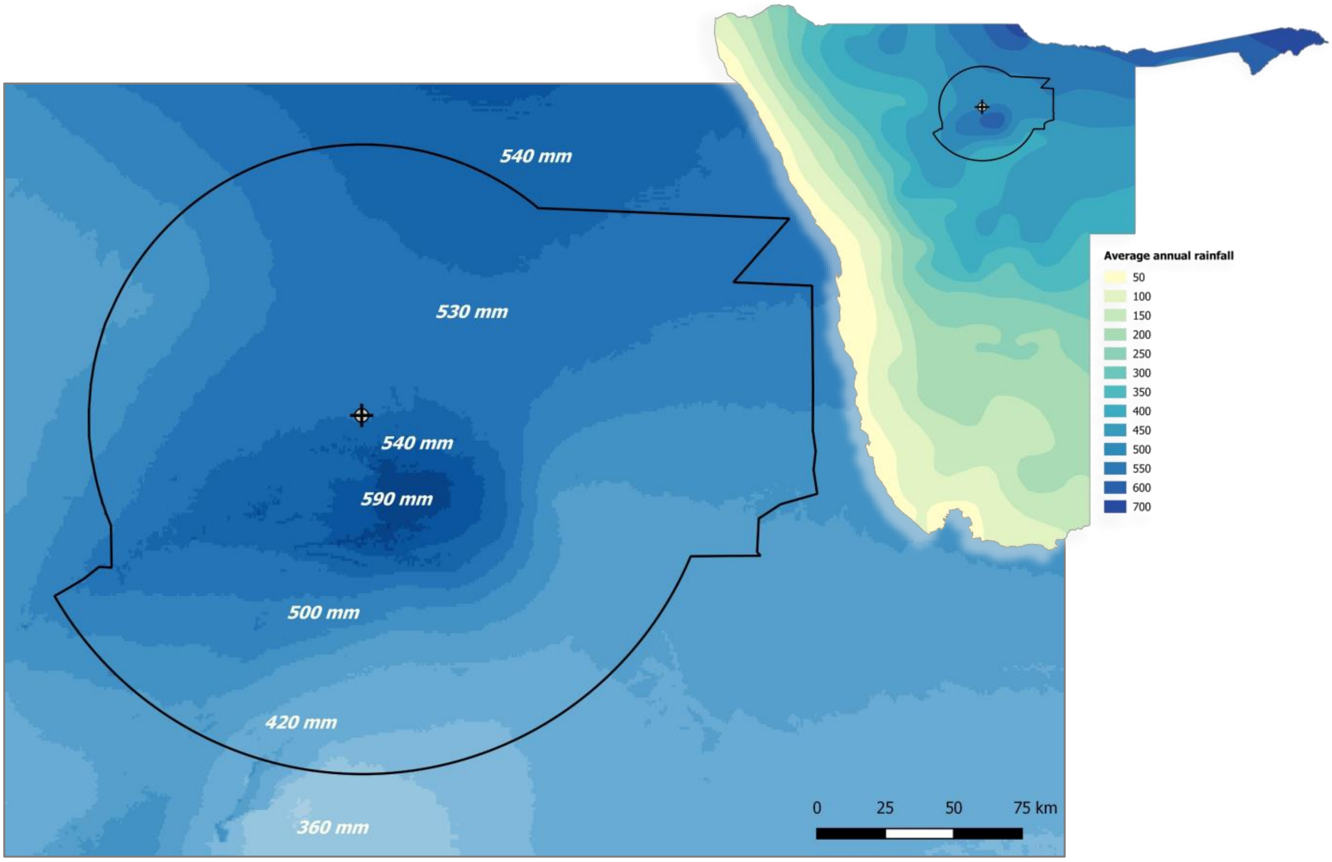

Figure 4. The distribution of long-term annual rainfall in the Otjikoto harvesting area (black polygon). Data source: WorldClim database version 2 (Fick & Hijmans, 2017; http://www.worldclim.org/). Inset: average rainfall over Namibia (source: Mendelsohn et al. 2002).

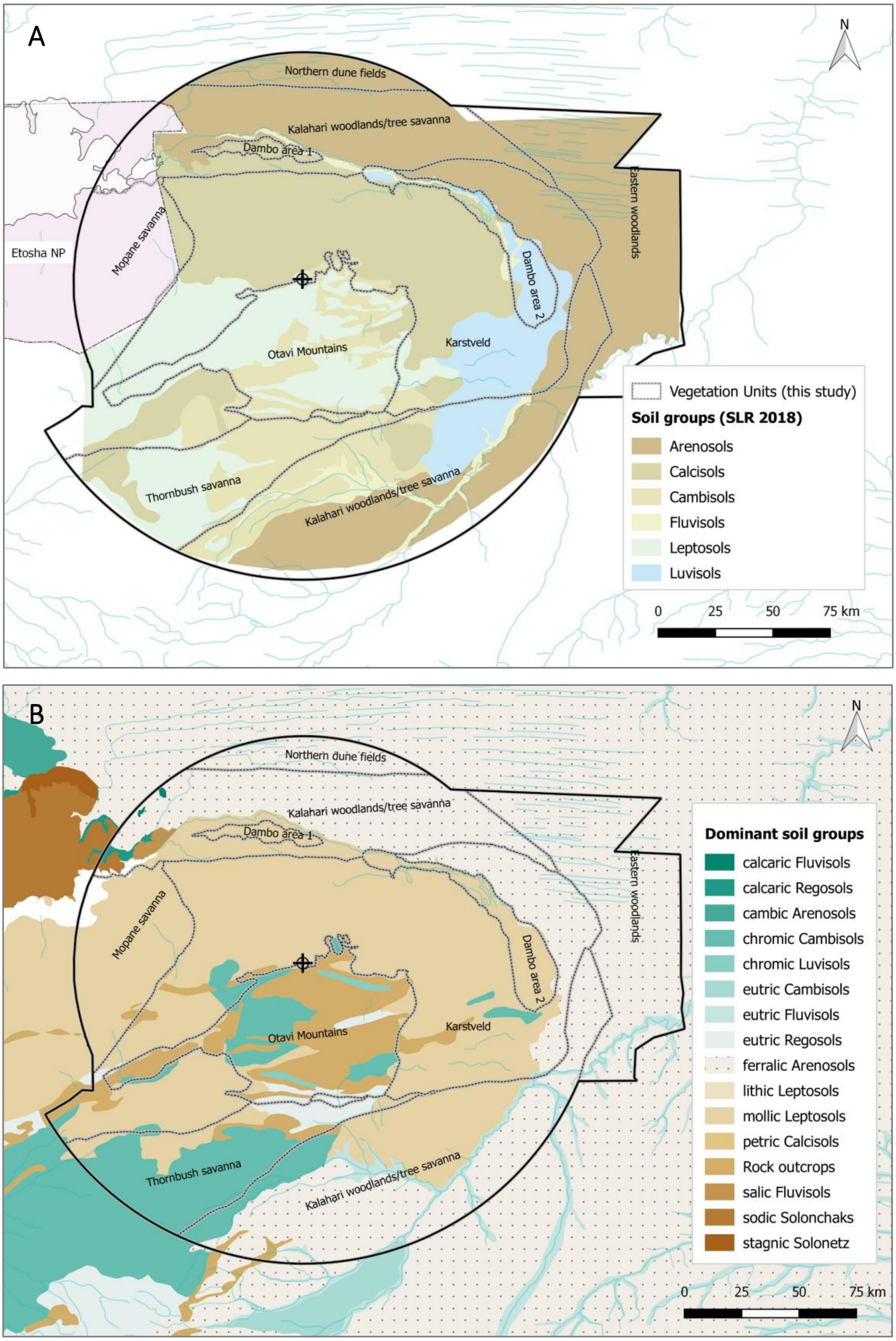

Figure 5. Two soil classifications showing remarkable congruence, both overlain with the vegetation types as defined in the current study. A) Soil groups according to the specialist study for the current project (SLR 2018). This study was limited to the harvesting area and excluded Etosha National Park. B) Dominant soil groups according to the national soil database (available for the whole study area).

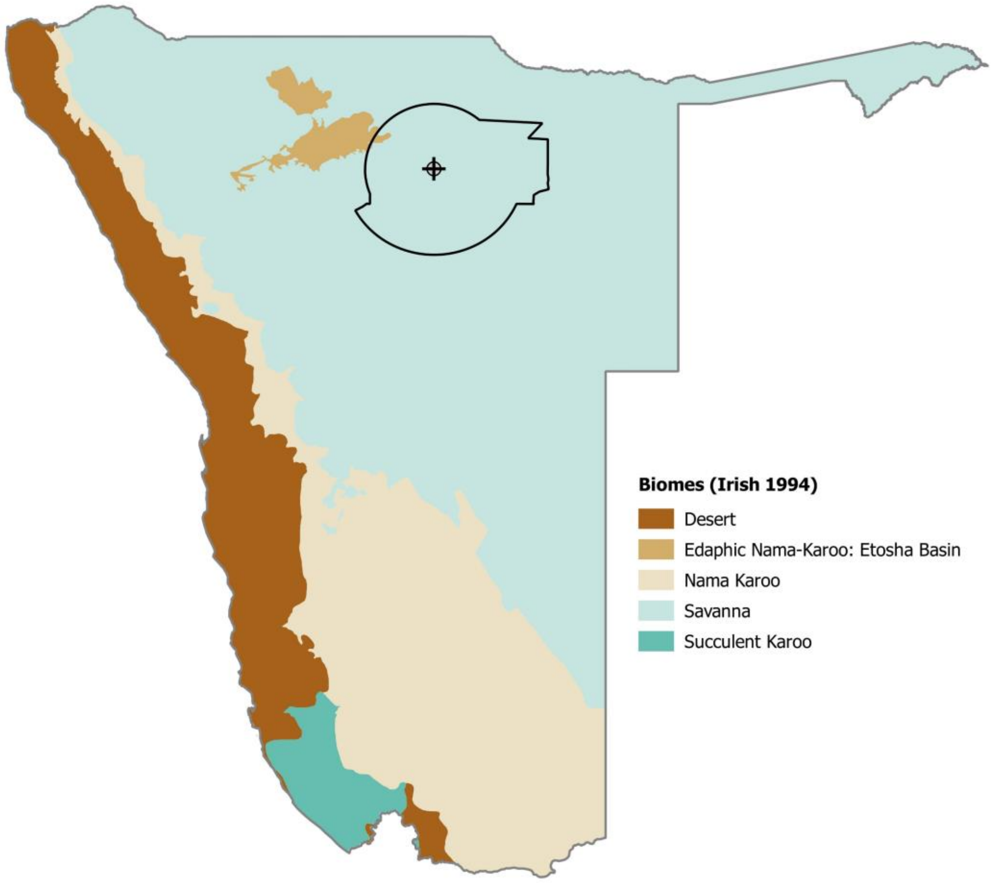

Figure 6. The location of the harvesting area relative to the biomes of Namibia according to Irish (1994).

7.6 General diversity and endemism patterns

Species lists for the harvesting and Project Site are provided as Appendices II and III. The Project Site and harvesting area tend to have a relatively high plant, reptile and mammal species richness, while moderate richness for amphibians (Figure 7). In terms of endemism, the Project Site falls in an area of intermediate plant endemism, with relatively few endemic mammal and reptile species (Figure 8). In the harvesting area, plant and mammal endemism tend to be intermediate in the Otavi Mountain areas, which range south and southwest of the Project Site, while low in the north-eastern parts of the harvesting area (Figure 8). Reptile endemism tend to be low throughout the study area (Figure 8).

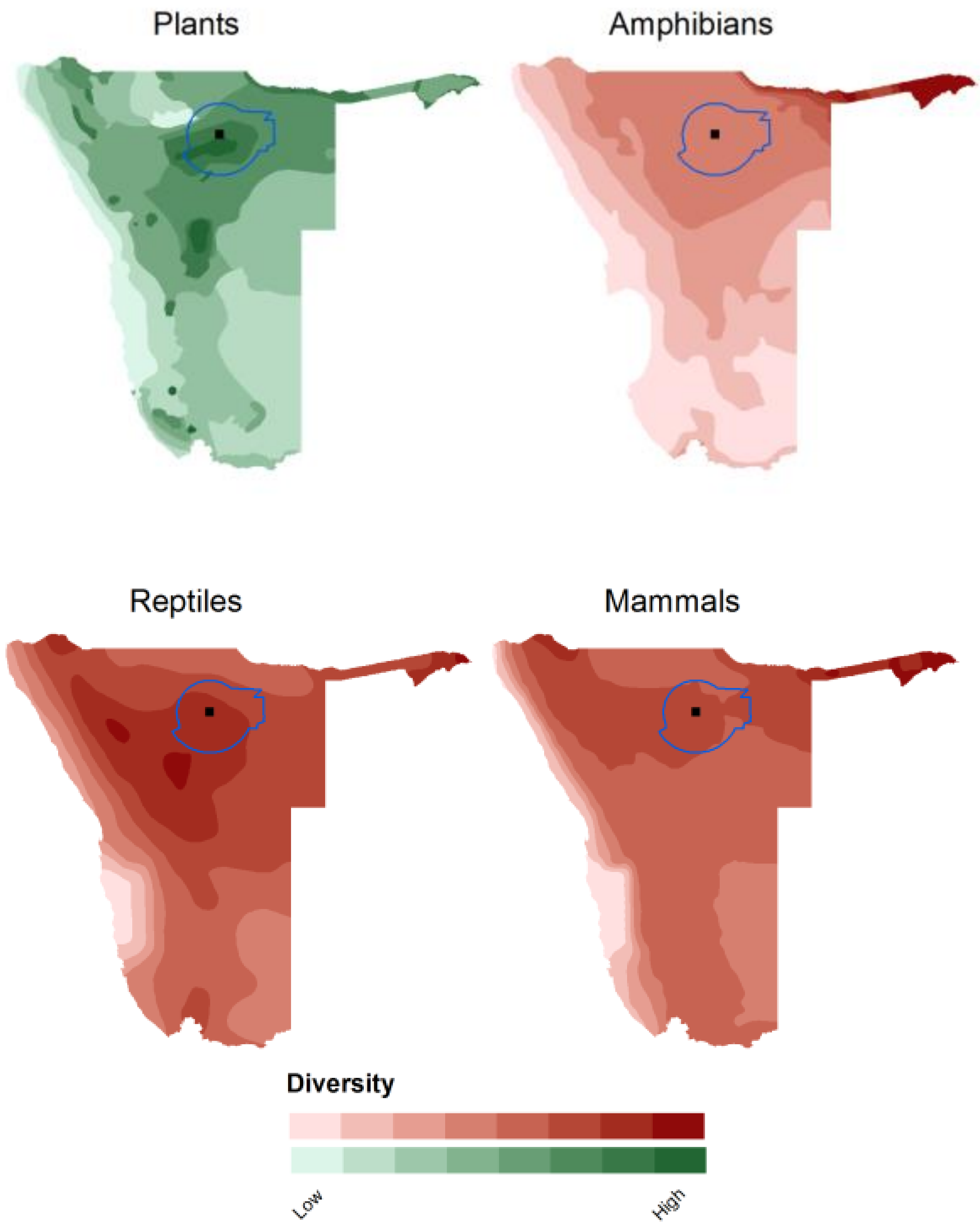

Figure 7. The Project Site and harvesting area in relation to diversity patterns of plant, amphibian, reptile and mammal species in Namibia.

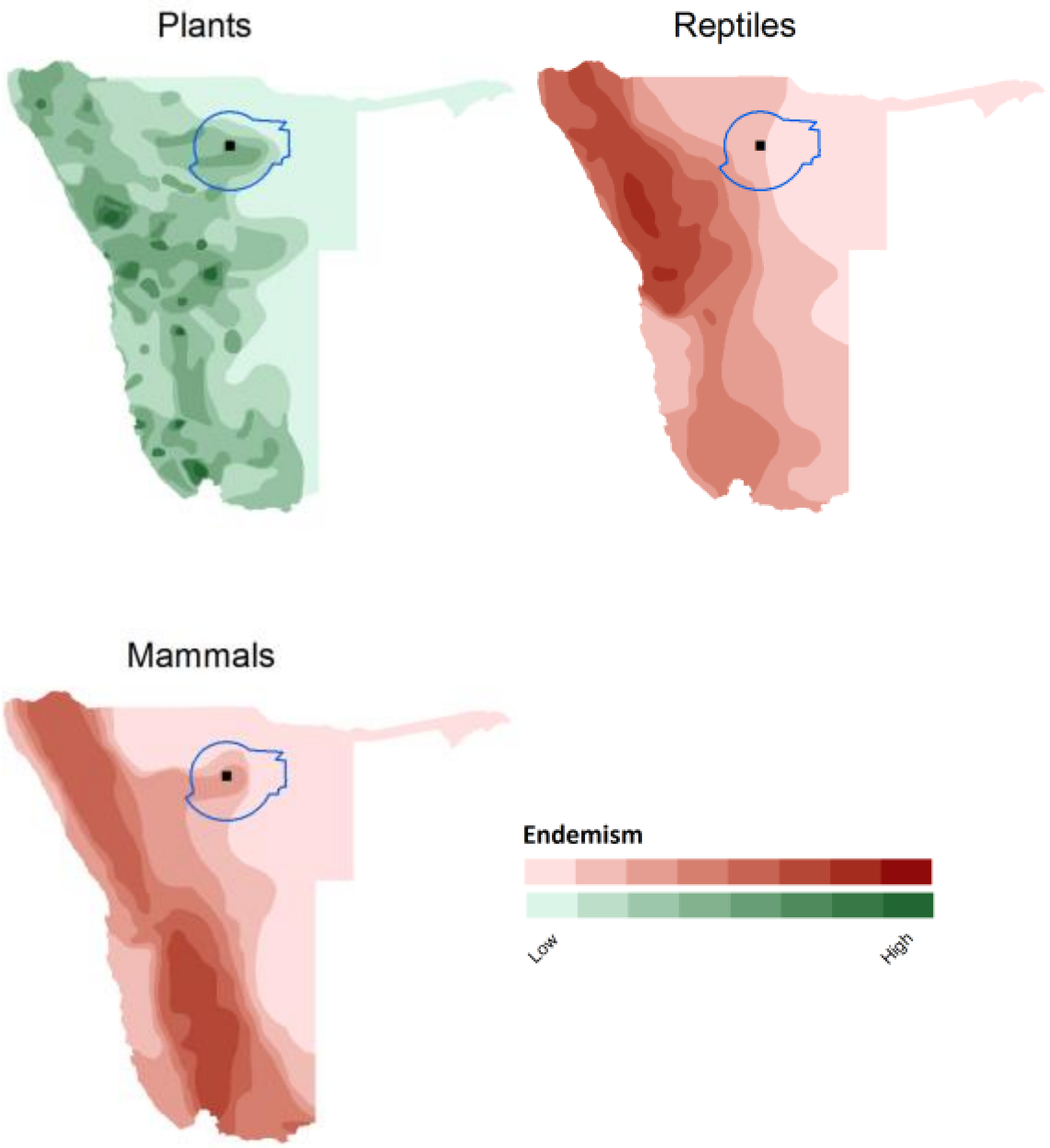

Figure 8. The Project Site and harvesting area in relation to endemism patterns of plant, reptile and mammal species in Namibia

7.7 Floristic diversity, endemism and conservation issues

The proposed site for the Project Site lies in a highly compromised and bush encroached area of the Tsumeb townlands, which falls within the Karstveld valley zone. A low number of protected trees occur here, and some endemic herbs are present, none of whose threat status will change as a result of the Project Site's construction here.

Plant species diversity in the harvesting area is regarded as very high, at over 500 taxa (Mendelsohn *et al.* 2002). This may be ascribed in part to topographic/niche diversity and high rainfall. Endemicity is also high, which is consistent with the presence of the dolomite mountains and hills of the Otavi Highlands, which has also long been recognised as a centre of diversity and endemism within Namibia and includes several narrow endemic species (e.g. Maggs *et al.* 1998, Craven & Vorster 2006). In general, mountains are noted for their high diversity and endemism, *inter alia* because of higher niche diversity and the effect of altitude, which often results in zones of higher moisture availability (Figure 4) and lower temperatures, as well as the presence of relict species from earlier geological times (palaeoendemics) and/or speciation (neoendemics) (e.g. Hilliard 1994, Craven 2002, Barnard 1998, Mendelsohn et al. 2002). Figure 9 indicates quarter-degree squares where recorded endemic species numbers are high, with most squares recording between 11 and 16 endemics. The Otavi mountain lands' importance as plant habitats is further underlined by the tendency for it to support relatively higher numbers of protected tree species (Figure 10).

7.8 Vertebrate diversity, endemism and conservation issues

7.8.1 Amphibians

A moderate number of amphibian species could potentially occur[10] at the Project Site (14 species) and in the harvesting area (18 species). Of these, no species are of conservation concern except the endemic *Poyntonophrynus damaranus* (Damara pygmy toad), which is a Data Deficient species (suspected but not definitely known to be endangered because of insufficient information, Griffin

[10] The likelihood of finding a species of any taxon (vertebrate and invertebrate) in a particular area is a complex function of a range of factors from their specific habitat requirements (which might be catholic or highly specialised), through climatic variation, to their specific population biology and abundance (abundant species tend to be found everywhere, rare species are seldom found). In this report, "potentially occurring" means that their distribution ranges overlap with the particular area, but does not imply that their habitat requirements will be met on the area.

When referring to the Project Site itself, the available habitat is relatively simple and uniform, hence only a portion of these species could ever be found there. Additionally, with the Project Site being fenced, much of the surrounding habitat disturbed in some way and a lot of human activity all around, it is highly unlikely that any of the larger mammal or reptile species would ever occur here, regardless of their theoretical distribution ranges.

When referring to the larger harvesting area, the chances are high that the habitat requirements of all these species will be met at least once, but their population biology and climatic variation will still influence this. A lack of good data on all species' habitat requirements prevents a very deep analysis of their chances of occurring on any given site. With the principal aim here being a categorisation of the sensitivity of areas, we therefore stick to these broad categories of potential occurrence, especially for the larger harvesting area.

2003) and which potentially occur in the harvesting area. Another endemic species, *Poyntonophrynus dombensis* (Dombe dwarf toad), may also occur in the harvesting area. The spotted rubber frog, *Phrynomantis affinis*, is a rare[11] species that may occur at both the Project Site and in the harvesting area. No amphibian species are currently protected in Namibia.

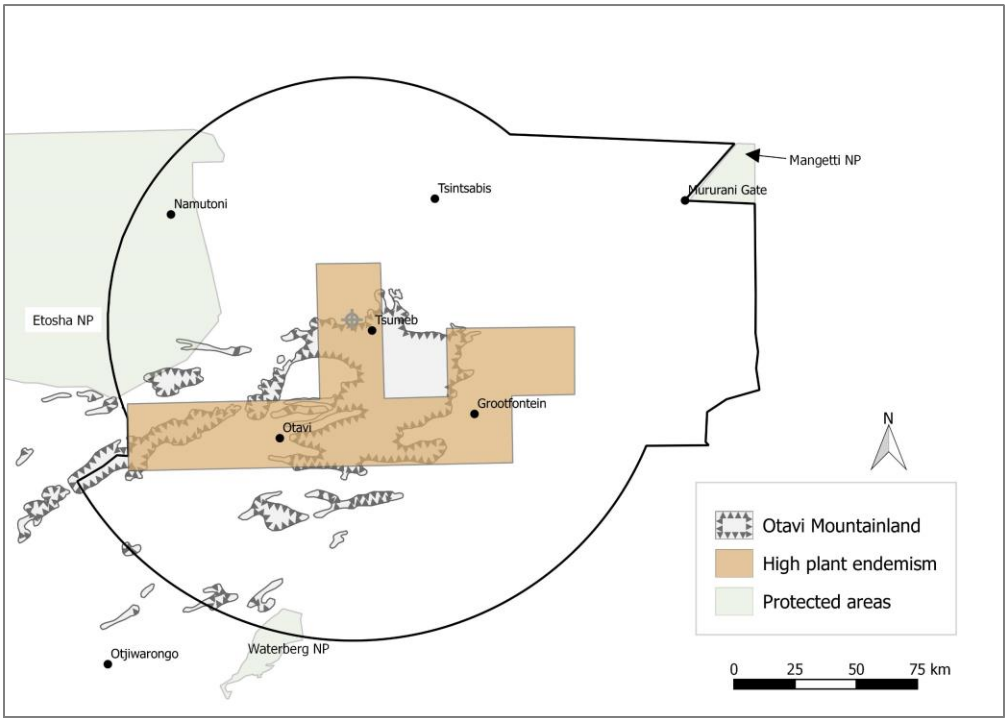

Figure 9. Areas of known high plant endemism clearly overlying the Otavi mountain lands (grey), but not captured in any of the current protected areas.

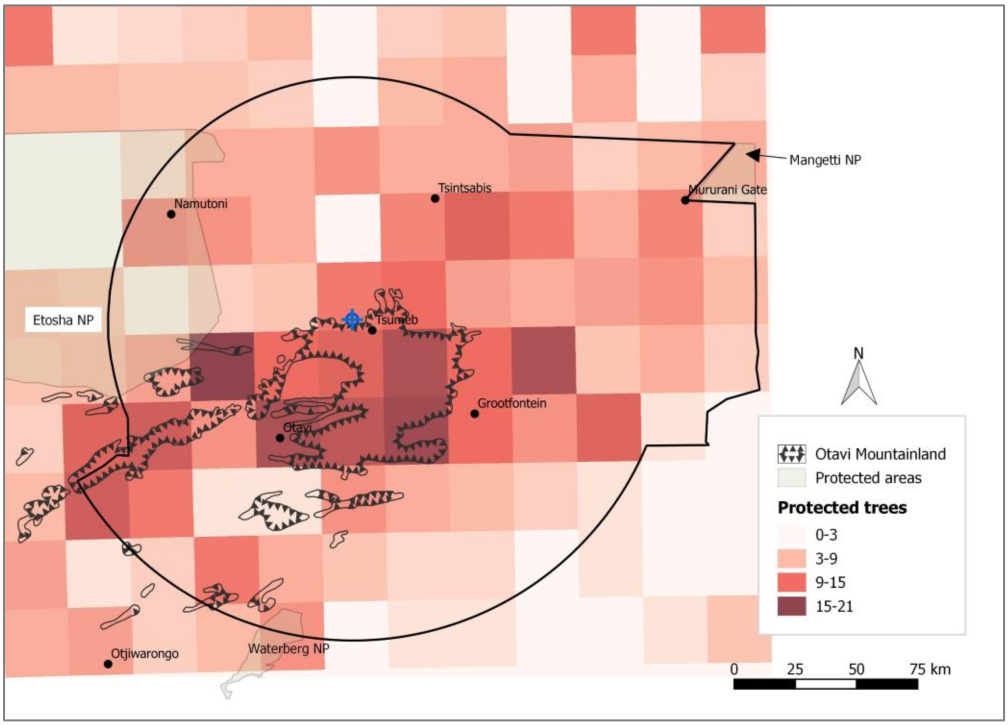

Figure 10. The distribution of the density of protected tree species in the study area. The highest numbers are concentrated around the Otavi mountain lands and not in the existing protected areas.

[11] By "rare" we mean a taxon with small population size which are not presently endangered but are potentially at risk (Griffin 2003)

Table 5. A summary of the conservation status of amphibian species potentially occurring at the Project Site and in the harvesting area. The data are from the IUCN database extracted for a 1km radius around study site centres and the status of expected species from the IUCN Red List and Griffin (2003).

Category	Amphibian species	
	Project Site	Harvesting area
Critically Endangered	0	0
Endangered	0	0
Vulnerable	0	0
Near Threatened	0	0
Data Deficient	0	1
Rare	1	1
Endemic	0	2
Protected in Namibia	0	0
Species richness	14	18

7.8.2 Reptiles

The Project Site (53 species) and harvesting area (72 species) has a relatively high potential reptile diversity, but low number of endemic species (

Table 6).

No Critically Endangered or Endangered category species occur at the Project Site or in the harvesting area. Three species classified as Vulnerable in Namibia (Griffins 2003) may potentially occur at the Project Site and harvesting area, namely: *Psammobates oculiferus* (serrated/Kalahari tent tortoise), *Python natalensis* (southern African python) and *Varanus albigularis* (Veld leguaan). One species, *Psammophis jallae* (Jalla's sand snake), is considered Data Deficient. Endemic reptile species that potentially occur include: *Leptotyphlops labialis* (Damara worm snake), *Lygodactylus bradfieldi* (Namibian dwarf gecko), *Cordylus jordani* (Namibian girdled lizard; only parts of harvesting area), *Naja nigricollis nigricincta* (Western spitting cobra; only parts of harvesting area), *Prosymna frontalis* (Southwestern shovel-snout snake; only parts of harvesting area) and *Psammophis leopardinus* (Leopard whip snake; only parts of harvesting area). Four reptile species that potentially occur in the harvesting area are protected in Namibia.

Table 6. A summary of the conservation status of reptile species that potentially occur at the Project Site and in the harvesting area. The conservation status per species is according to the Namibia Biodiversity Database for available species and according to Griffin (2003) for species not listed in the database. The legal status is according to the Namibia Conservation Ordinance 4 of 1975 as amended.

Category	Reptile species	
	Project Site	Harvesting area
Critically Endangered	0	0
Endangered	0	0
Vulnerable	3	3
Near Threatened	0	0
Data Deficient	1	1
Rare	0	0
Endemic	2	6
Protected in Namibia	4	4
Species richness	53	72

7.8.3 Mammals

Mammal species richness at the Project Site (73 species) and harvesting area (102 species) are high (

Table 7). A relatively large number of mammal species of conservation concern potentially occur at the Project Site and in the harvesting area (

Table 7). One Critically Endangered (IUCN) species, Diceros bicornis (black rhino), and one Endangered species potentially occur in the harvesting area, namely Lycaon pictus (wild dog). At the Project Site and harvesting area eight mammal species are considered Vulnerable (IUCN), namely Acinonyx jubatus (cheetah), Felis nigripes (black-footed cat), Giraffa camelopardalis (giraffe), Panthera pardus (leopard), Smutsia temminckii (pangolin), Equus zebra (Hartmann's mountain zebra), Loxodonta africana (elephant) and Panthera leo (lion). Near threatened species include: Ceratotherium simum (white rhino), Hipposideros vittatus (Commerson's leafnosed bat), Parahyaena brunnea (brown hyaena) and Equus quagga (plains Zebra). No rare mammal species are expected at either site or in the harvesting area. Only one endemic mammal species is expected at the Project Site, Elephantulus intufi (bushveld sengi). An additional three endemic species potentially occur in the harvesting area, namely Equus zebra (mountain zebra), Herpestes flavescens (Kaokoveld slender mongoose) and Petromus typicus (dassie rat), but none of them are expected at the Project Site. A large number of locally protected species potentially occur at the Project Site (20 species) and in the harvesting area (27 species,

Table 7).

Table 7. Summary of the expected occurrence of mammal species at the Project Site and in the harvesting area in terms of conservation (IUCN) and legal status (Namibia Conservation Ordinance), endemicity (Griffin 2003) and species richness.

Category	Mammal species	
	Project Site	Harvesting area
Critically Endangered	0	1
Endangered	0	1
Vulnerable	5	8
Near Threatened	3	4
Data Deficient	0	0
Rare	1	2
Endemic	1	4
Protected in Namibia	20	27
Species richness	73	102

7.9 Floristic habitats (vegetation zones) of the harvesting area

There is considerable overlap between the different vegetation zones/habitats regarding plant species of concern. Nevertheless, some are more important than others because they support species of conservation concern, or would be difficult to restore after high intensity clearing. In addition, two historic impacts must be acknowledged: the felling of over four million large trees for the Tsumeb and Abenab mines in the 1970s (more on this below) and the more recent large-scale (non-selective) use of arboricides (defined as pesticides by FSC) in vast areas within the harvesting area. Both have had severe consequences for large trees, most of them protected species but also large individuals of non-protected species such as *Acacia luederitzii*. The latter are often important as habitat and refuge for fauna, as well as for soil retention and cooling, and for nitrogen fixation.

The study area comprises four main vegetation zones, some of which can be sub-divided to give nine zones in total (these are depicted in Figure 11 and described further below). The four main zones are listed below:

1. Karstveld, comprising the central zone and the bulk of the harvesting area, including the Otavi Mountain lands.
2. Mopane Savanna in the west of the Karst area, bordering the Etosha National Park.
3. Kalahari Woodlands/Kalahari Tree Savanna to the north, east and south-east of the Karst zone. This includes the Northern Dune fields and Eastern Woodlands, respectively in the far north and east of the harvesting area, and two similar dambos (Dambo 1 and Dambo 2).
4. Thornbush Savanna south of Otavi.

7.9.1 Karstveld

Most of the central part of the harvesting area is Karstveld (Figure 11). This relates to the Mountain Savanna and Karstveld vegetation zone of Giess (1998), which is essentially equivalent to the Karstveld of Mendelsohn *et al*. (2002) which, particularly on the mountain slopes, is characterised by a high density and diversity of broadleaved trees and shrubs (i.e. broadleaved woodland), including important species such as *Combretum imberbe*, *Ficus* spp., *Sclerocarya birrea, Kirkia acuminata, Berchemia discolor* and *Spirostachys africana* (Appendix 1). In addition, numerous endemic, near endemic and otherwise protected non-woody species are known to occur (Appendix 2). The valleys and sandveld patches in between carry a slightly lower diversity of broadleaved trees and shrubs with thornveld components such as *Dichrostachys cinerea* and *Acacia* spp. more prevalent, often forming dense areas of encroachment (i.e. mixed woodland). *Hyphaene petersiana* (the fan palm) is also common in places where water stands for a while in the rainy season. Dense stands of ancient and valuable *Ficus sycomorus* have also been observed.

Numerous endemic and/or protected geophyte species have been recorded in this zone, but it is likely that they will not be heavily impacted by bush harvesting due to the likely survival of their subterranean corms or tubers.

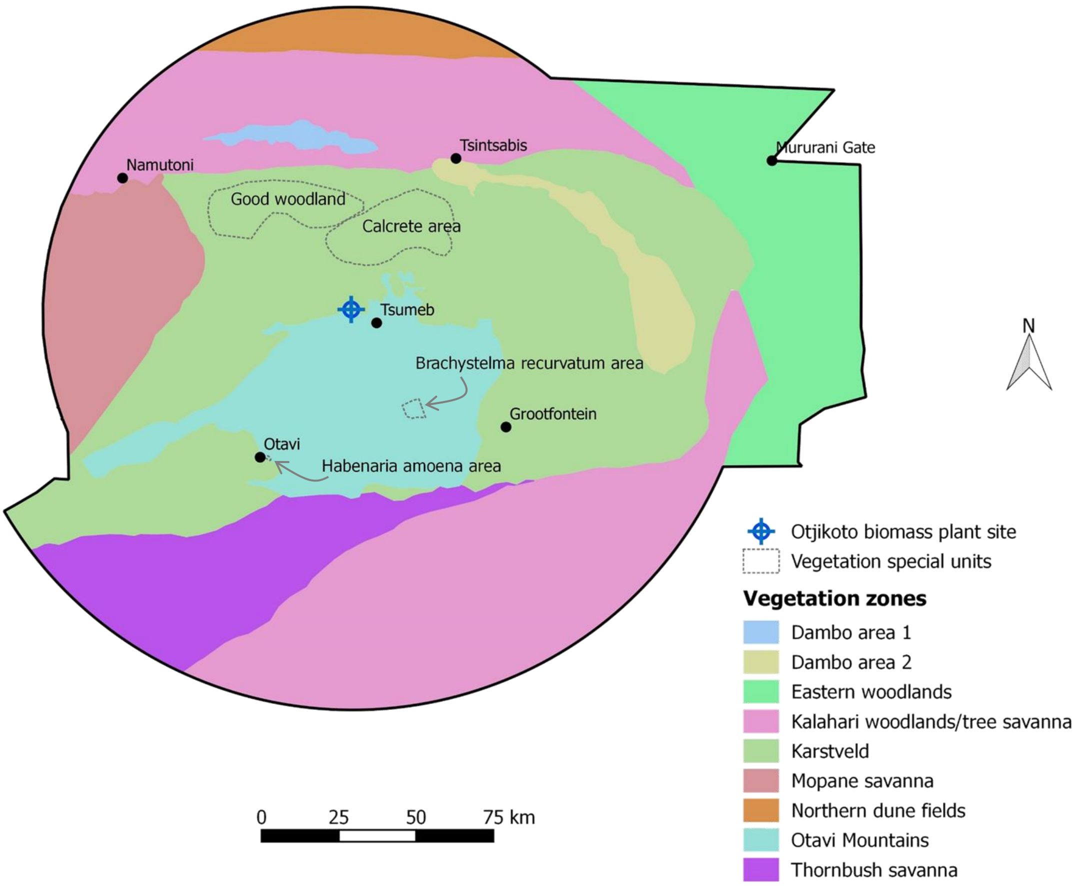

Figure 11. A map of the harvesting area showing the vegetation zones and the location of special zones defined by specific plant populations or particularly good condition habitat.

Many endemic non-woody species occur that will likely be badly impacted by mechanical harvesting. These include *Crassocephalum coeruleum, Petalidium rautanenii, Aloe* spp., *Duvalia polita, Huernia oculata* and *Stapelia* spp. However, they are reasonably widespread, or are most common on rocky hill and mountain slopes. The Karstveld zone may roughly be divided into:

- Dolomites mountains, koppies and ridges.
- Narrow valleys lying between the mountains and koppies.
- Surrounding calcareous plains.

Dolomite mountains, koppies and ridges

Biogeographically forming part of the Otavi mountain land (Figure 11; Otavi Mountains), which is known to harbour numerous endemic and protected species, this is a highly diverse habitat, incorporating permanent spring areas and carrying a very high density of large trees, many belonging to protected and/or range-restricted species. It also harbours several endemics with a preference for limestone substrates, such as *Ornithoglossum calcicola* and *Petalidium rautanenii,* with the latter common. This zone supports one of the best developed and valuable woodland habitats in the country. Many large specimens of protected and/or restricted range species, such as *Sclerocarya birrea* (marula), *Berchemia discolor* (birdplum), *Pachypodium lealii, Lannea discolor, Combretum imberbe* and others are common, while others, such as *Ficus* spp. are more scattered. Species of conservation concern entirely or largely restricted to this zone include *Jamesbrittenia dolomitica, Jamesbrittenia fragilis, Heteromorpha stenophylla* var. *stenophylla, Cyphostemma juttae* and *Erythrina decora*. The notable population of *Pachypodium lealii,* an iconic pachycaul, present in the study area occurs virtually exclusively on these slopes. Furthermore, large scale damage here would substantially and negatively alter the conservation status of species such as *Kirkia acuminata* and *Gyrocarpus americanus,* which at present are not protected but would have to be urgently reassessed.

Valleys

The valleys between the highlands are home to many of the same tree species of concern as the highlands, but in lower densities overall. The range-restricted and habitat restricted non-woody species *Heteromorpha stenophylla* var. *stenophylla, Jamesbrittenia dolomitica* and *Jamesbrittenia fragilis* are absent, as are *Pachypodium lealii* and *Gyrocarpus americanus.* On the other hand, *Burkea africana* and *Pterocarpus angolensis* are present in places and there are areas where dense stands of *Olea europaea* (which is an evergreen tree) occur. *Acacia erioloba, Ziziphus mucronata, Albizia anthelmintica* and *Combretum imberbe* (all protected) are reasonably common, *Ficus* spp. are present, and non-protected fruit-producing species such as *Grewia* spp. and *Ximenia* spp. occur throughout. *Spirostachys africana* (tamboti) is present in high numbers and will be of concern, as will large specimens of *Kirkia acuminata.* Several useful species that do not enjoy protection are well represented and observations in charcoal harvesting areas indicate that the larger specimens will need careful monitoring to ensure that they are not removed. These include *Philenoptera nelsii, Peltophorum africanum, Combretum apiculatum* and *Ozoroa paniculosa*.

Surrounding calcareous plains

The Karstveld plains outside of the mountain-valley zones carry many of the same tree species of concern as the valleys. Some, such as *Sclerocarya birrea* (marula) and *Berchemia discolor* (birdplum) are more scattered, but *Spirostachys africana, Combretum imberbe, Acacia erioloba* and *Ficus* spp. are more common. In the central area of these plains there appears to be a calcrete area where the water table is regarded as particularly shallow (P. Oosthuizen, famer, *pers. comm.*). This area (Figure 11) appears to carry a slightly different species complement, with numerous examples of *Securidaca longepedunculata,* high numbers of *Combretum imberbe,* and the dense stands of ancient and valuable *Ficus sycomorus* previously mentioned. The complement of non-woody species of concern is likely the same as that of the valleys. Note that large tracts of this zone have been treated with arboricides, which has had detrimental effects on protected and non-target species, so it is particularly important to conserve what is left.

7.9.2 Mopane Savanna

Just east of the Etosha National park (ENP) there is an area of Mopane Savanna (Figure 11), which is recognised as distinct by Giess (1998) but is included in the Karstveld of Mendelsohn *et al.* (2002). Giess notes that it shares many species with the latter and is related to it. It is characterised by a prevalence of *Colophospermum mopane*, as well as quite high numbers of *Commiphora glandulosa.*

On the ground it is clearly dominated by mopane, but it is important to note that the mopane in this zone is not always dense, invasive scrub but in some areas is composed partially or largely of substantial trees (compare Figure 12a and b). In the latter context mopane is a protected species, and so of concern in this zone. Other tree species of concern are *Combretum imberbe, Spirostachys africana, Albizia anthelmintica, Boscia albitrunca* and *Berchemia discolor*.

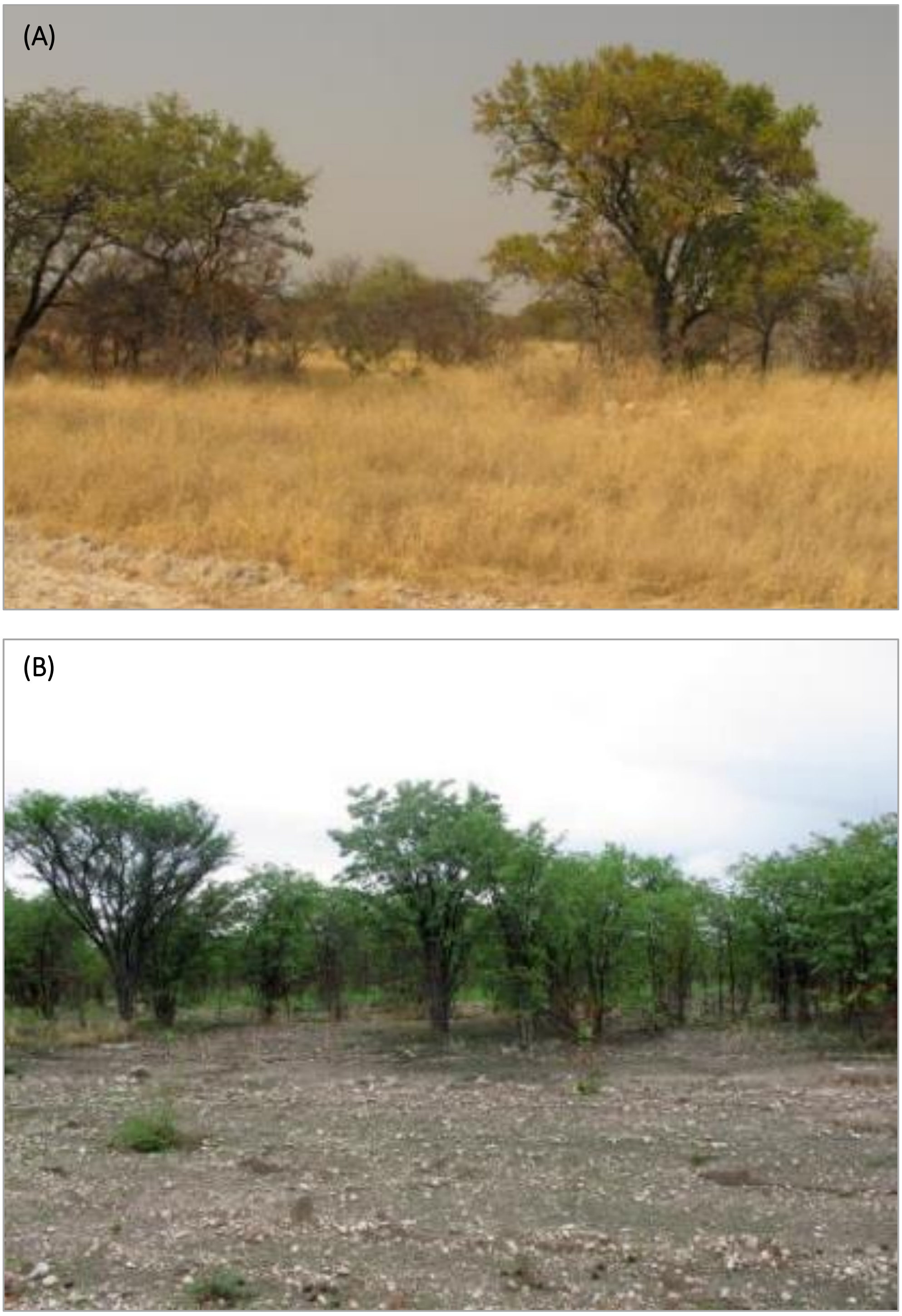

Figure 12. Mopane Savanna, east of Etosha. (A): not encroached, (B): encroached.

7.9.3 Kalahari Woodlands/Tree Savanna

With the exception of an area of consistently deep sands (Figure 11; Northern Dune Fields) directly to the north of Tsintsabis, the Kalahari Woodlands/Tree Savanna is essentially a low dune field lying mainly to the north, east and south-east of the Karst zone, comprising Kalahari Sandveld carrying both broadleaved and fine-leaved woody species, such as *Acacia* spp. (including the protected *A. erioloba*), *Philenoptera nelsii, Peltophorum africanum, Boscia albitrunca, Terminalia sericea, Combretum collinum, C. apiculatum,* and others, as well as *Hyphaene petersiana*, which can form quite dense stands (Figure 11).

Along margins of drainage lines and in zones encircling depressions where water collects in the rainy season important tree species, such as *Ficus petersii, Acacia erioloba, Spirostachys africana,* and *C. imberbe* are common and represented by large, mature individuals. Two of the most important areas for this are shown in Figure 11 (Dambo area 1 and 2), but depressions are scattered throughout the Kalahari woodland and all omiramba, of which several lie towards the south-eastern part of this zone between the Waterberg area, and are of very high concern.

In the east and the far north, the important broad-leaved species are concentrated on the dunes (although not confined to them), while important fine leaved species, such as *Acacia erioloba*, are more common in inter-dune areas.

Tree species of high concern recorded for this zone include, *inter alia, Schinziophyton rautanenii, Berchemia discolor, Baikiaea plurijuga, Burkea africana* (Figure 14)*, Dialium englerianum, Guibourtia coleosperma, Albizia anthelmintica, Pterocarpus angolensis, Sclerocarya birrea* and *Spirostachys africana,* and stands of *Ficus sycomorus* are very likely to occur. Many species that are encountered in this zone are utilised for uses such as food, medicine, timber or cash crops and many are important sources of food and shelter for birds and other animals. Some of the species fall into all those use categories. Non-woody species of concern likely to be affected by mechanical harvesting are the two stapelias, *Huernia oculata* and *Orbea lugardii* (all protected species). No other herbs are of high concern in this zone.

This zone is difficult to categorise because it includes diverse areas. In the dune areas there are inter-dune valleys where broadleaved woodland is replaced by mixed woodland or predominantly *Acacia* woodland. On the deep dune sands there are stands of extremely valuable broad-leaved woodland, especially in the far eastern parts, which not only support important protected species such as *Pterocarpus angolensis* and *Burkea africana* (Figure 14), but also carry non-protected species such as *Securidaca longepedunculata, Combretum collinum* and *Combretum psidioides* that have never faced large-scale threats before and thus do not enjoy protected status but which will be substantially affected by the harvesting of such vast areas unless careful controls and checks are implemented and enforced. Figure 11 offers a rough indication of the border of the most important high-value Eastern woodland area. Note that this is a rough indication only. Sensitivity varies across the zone.

Figure 13. Depressions (dambos) south of the northern omuramba and in the Kalahari woodlands are surrounded by large trees, mostly belonging to species of conservation concern. Omiramba and dune woodland areas are also of high concern.

Figure 14. Large Burkea africana *in dune woodland of high concern in the east of the proposed harvesting area.*

7.9.4 Thornbush savanna

To the south-west of Otavi there is a belt of Thornbush Savanna characterised by a high prevalence of *Acacia* spp., interspersed with scattered *Boscia albitrunca* and patches where *Philenoptera nelsii, Peltophorum africanum, Kirkia africana, Combretum imberbe* and (occasionally) *Colophospermum mopane* are common. In addition, there are dense stands of *Olea europaea* in places that will need to be conserved in order not to change the conservation status of this species. None of the non-woody species of concern that occur in this zone are likely to have their conservation status changed by this project (over the long term), although *Pteronia eenii* is likely to be affected by large-scale mechanical harvesting.

Large tracts of this zone have been treated with arboricides, which has had detrimental effects on protected and non-target species. Current bush-clearing practices, especially over clearing (SAIEA 2016), seem to favour the conservation of only large individuals of protected species such as *Boscia albitrunca.* This is a poor management practice that will not result in a diverse, resilient and productive savanna and is therefore unacceptable as an approach in the management of impacts of the Encroacher Bush Biomass Power Project.

7.10 Sensitivity per taxon

7.10.1 Vegetation

The Karstveld woodlands (Figure 11) experienced a very high environmental impact during the 1970s at which time Piet le Roux, the first Professional Forester in the then South West Africa, based in Grootfontein, recorded the felling of an estimated 4 million large indigenous trees, mainly tamboti (*Spirostachys africana*, now a protected species), for props for the Tsumeb and Abenab mines. He noted that they were speedily replaced by invasive species such as *Dichrostachys cinerea* and *Acacia mellifera* (Le Roux et al. 2009), and it is highly probable that the bush encroachment problem we see in that area today was, to a considerable extent, caused by this huge and unsustainable off-take of large trees enabling the proliferation of invasive pioneer bush species. Recovery of tamboti has been slow, and this project has the potential to set it back enormously if harvesting is not managed and monitored properly.

Large tracts of the valleys in the Karstveld zone have been treated with arboricides in the past (C. Mannheimer, pers. obs.), which has had detrimental effects on protected and non-target species. It is therefore particularly important to conserve what is left. The valley sub-zone is **Sensitive**. Within the Karstveld zone, the Dolomite mountains, koppies and ridges are **No-go** areas.

Embedded in the Karstveld is a high-value woodland area (Figure 11; High-value woodland). This area is encroached but has not been chemically treated and still carries a healthy complement of trees. It should be treated with extra care, as well as the calcareous plains sub-zone (Figure 11).

Close to Otavi there is a site where the only Namibian record of the orchid *Habenaria amoena* was collected (Figure 15). Although this is a geophytic species, it is of concern due to its apparent rarity. Similarly, Farm Harasib south of Tsumeb is the locality for the only known collection of the geophyte

Brachystelma recurvatum. It was found on a grassy foot slope. Both these special species sensitivity zones are therefore **No-go** areas (Figure 15).

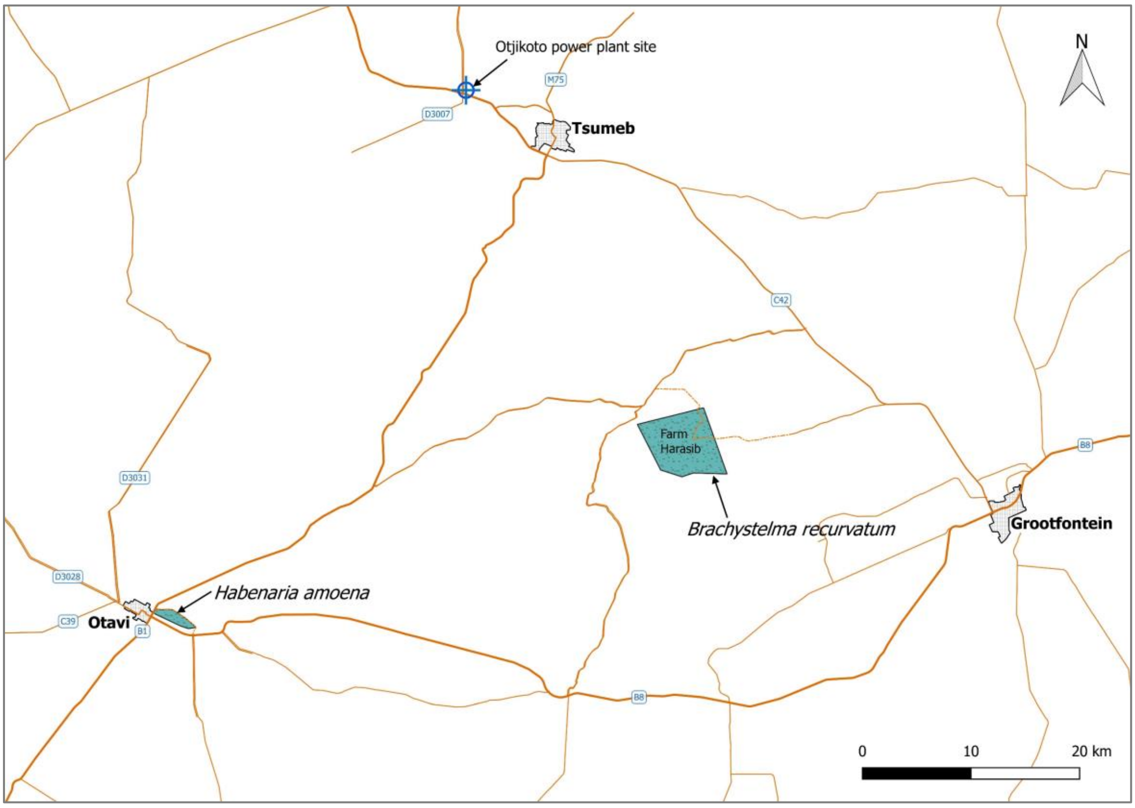

Figure 15. The location of two plant species of special significance: one area near Otavi where Habenaria amoena *is known to occur and the other on farm Harasib where* Brachystelma recurvatum *has been recorded. See text for more detail on this issue.*

The Kalahari woodland/tree savanna zone (Figure 11) is **Least sensitive** in previously degraded areas dominated by low *Terminalia sericea*. However, large specimens of species such as *Schinziophyton rautanenii* (Mangetti), *Acacia erioloba*, *Spirostachys africana* (tamboti) and other protected species are scattered throughout and concentrated around pan areas. Where individuals of these species occur, particularly where their population density is high, the immediate area should be considered as **Sensitive**. Also, areas such as near Tsintsabis where large individuals of *Baikiaea plurijuga*, *Burkea africana, Combretum collinum, Spirostachys africana* and *Sclerocarya birrea* occur are considered to be **Sensitive**. The drainage lines and depressions (dambos) in the Kalahari woodland/tree savanna zone should all be considered **Very sensitive** and all omiramba treated as No-Go zones.

The Eastern Woodlands and Northern Dune fields (Figure 11) can be divided into two main sub-zones. 1) The broad-leaved woodland on red dune sands, which are **Very sensitive** due to many large, mature broad-leaved trees, including *Combretum collinum*, *C. psidioides, Securidaca longepedunculata* and protected species such as *Pterocarpus angolensis, Burkea africana, Sclerocarya birrea, Albizia anthelmintica* and others. In contrast, 2) the mixed woodland and Acacia woodland on lighter and harder sands are Sensitive, because of fewer examples of large, important broadleaved species, but still with some present, and with high numbers of *Acacia erioloba, Ziziphus mucronata* and

Combretum imberbe. The many instances where these species have been cleared for agricultural purposes represent an additional and external threat that increases the risks to the species and ads to the sensitivity of the remaining examples.

The Thornbush savanna and Mopane savanna (Figure 11) are considered as **Least sensitive**.

The sensitivity rankings discussed above are summarised below in Table 8.

Table 8. Scores and rankings of sensitivity of different vegetation zones and sub-zones. See also Figure 16 for their geographical locations.

		Criteria and ranking (see Table footnotes)					
Vegetation Zone	Sub-zone	Conserv. Concern (Footnote 1)	Not prot., at risk (Footnote 2)	Large trees (Footnote 3)	Recovery potential (Footnote 4)	Historic/ poisoning (Footnote 5)	TOTAL
Karstveld	Mountains, koppies and ridges	3	1	3	3	1	11
	Narrow valleys	3	1	2	2	1	9
	Calcareous plains	2	1	2	2	1	8
Mopane Savanna		2	0	2	2	0	6
Kalahari Woodlands	Deep sandy plains (north of Tsintsabis)	2	2	2	1	0	7
	Interdune valleys	2	1	2	2	1	8
	Dunes	3	1	3	3	0	10
	Drainage lines and depressions	3	1	3	3	0	10
Thornbush Savanna		2	1	2	1	1	7

1. Density of species of conservation concern (protected, endemic, threatened, red data) High =3; Medium = 2; Low = 1
2. Presence of species not protected at the moment but whose present conservation status may be seriously compromised by large scale harvesting. Most prevalent = 2; Prevalent = 1; Not prevalent = 0
3. Presence of many large trees. High = 3; Medium = 2; few = 1
4. Recovery potential, taking soils and growth rate of prevalent species of concern into account. High = 1; Medium = 2; Low or none = 3
5. Historic impacts/arboricide poisoning. Yes = 1; No = 0

A map of the proposed harvesting area showing the sensitivity of the various vegetation zones identified in the harvesting area is provided in Figure 16.

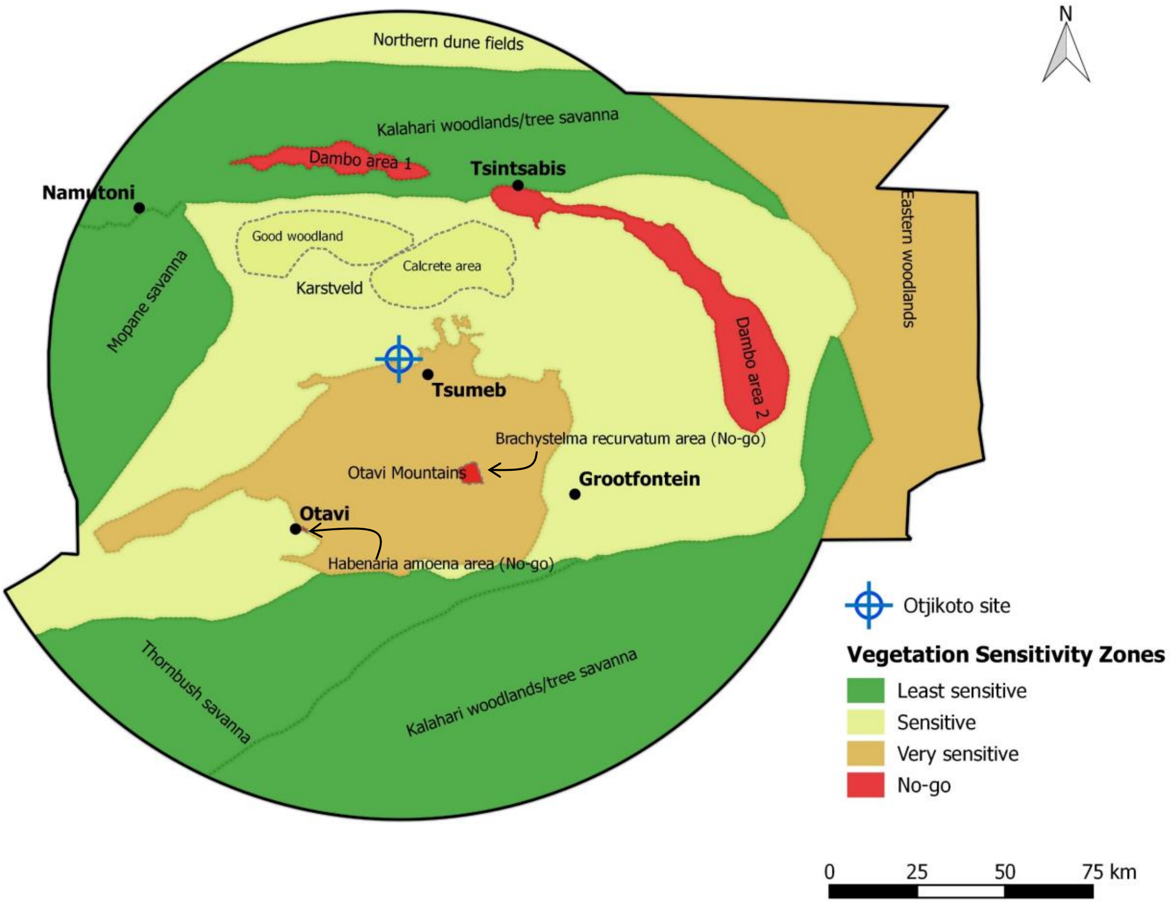

Figure 16. A map of the proposed harvesting area showing the sensitivity of the various vegetation zones identified in the harvesting area.

The dotted lines surround "special" zones, where extra care may have to be taken because of unique conditions (the two large areas in the Karstveld), or that are No-go because of the presence of very rare species (the *H. recurvatum* and *H. amoena* areas indicated with an arrow; see also Figure 15). Not shown are fine-scaled sensitive areas such as drainage lines, rocky outcrops, hills and isolated mountains, as well as concentrations of protected and threatened plant populations too fragmented or detailed to map at this scale.

7.10.2 Amphibians, reptiles and mammals

Amphibians

Several species will be more sensitive than others to the biomass related impacts, which warrants that a priority status is accorded to these species and their associated habitats. At a species level, the endemic Damaraland Pygmy Toad (*Poyntonophrynus damaranus*) potentially occurs in the southern parts of the harvesting area and is a Data Deficient species according to the IUCN. The only known population occurs in the Waterberg area. The taxonomy of the species is uncertain and very little is known about its habitat and ecology. It presumably breeds in temporary water bodies. Threats to this species are currently unknown. The Dombe Pygmy Toad (*Poyntonophrynus dombensis*) is endemic to

Namibia and prefers grassland with rock outcrops. It breeds in small, temporary steams. No threats to the Dombe Pygmy Toad are currently known.

Reptiles and mammals

The potential threats to reptile and mammal species of conservation concern at both the Project Site and in the harvesting area are summarized in Table 9 and Table 10, respectively.

The populations of several species of conservation importance may be negatively impacted by the construction and operation of the Project Site and the connecting power line at the Project Site. These species will be sensitive to mortalities or injuries caused by vehicles and machinery, to poaching for bushmeat (antelope species, leguaans) and illegal capture for medicinal and pet trades (e.g. pangolins, tortoises and pythons), loss of habitat, as well as noise, sight and light disturbances that displace or disrupt activities, including breeding.

In the harvesting area, many of the priority species prefer rocky habitats, thus disturbance of mountainous or rocky areas should be avoided, as well as drainage lines and ephemeral or permanent water bodies such as pans or vleis. Similar as at the Project Site, negative impacts on priority reptile and mammal species include killing of animals by vehicles and machinery, poaching for bushmeat and illegal capture for medicinal and pet trades, as well as noise, sight and light disturbances that displace or disrupt activities, including breeding.

The Project Site itself is not situated in an amphibian, reptile or mammal diversity hotspot area. Nevertheless, a rich reptile and mammal diversity potentially occur at the site. The Project Site also occurs in the ecotone zone where the Otavi mountain habitat meets the northern Karstveld plains and rocky outcrops in the immediate surroundings of the site (e.g. <1km radius), are considered to be sensitive habitat because rocky areas generally support higher diversity and are difficult or impossible to restore. Theoretically, given the above conservation characteristics of the Project Site, it would be rated as sensitive. However, the plains at the Project Site and its immediate surroundings are largely disturbed by past agricultural activities, the service roads, railway tracks, the existing Otjikoto power sub-station, mining activities to the west and a moderate to intensive degree of bush encroachment. The construction and operation of the Project Site will only add to this complement of disturbances, further fragmenting potential habitat for small vertebrates, while the noise, sight and other human-related disturbances probably deter most other large vertebrates to some extent. As such it is difficult to assign a sensitivity to the habitat on the Project Site in terms of amphibians, reptiles and mammals.

The harvesting area overlaps with the potential distribution ranges of a large number of mammal species and a modest number of amphibian and reptile species of conservation concern, some of which have specific habitat requirements. For example, Hartmann's mountain zebra, leopard and Commerson's leaf-nosed bat are expected to be more closely associated with the Otavi Mountain vegetation zone. The Eastern Woodland vegetation zone is Least Sensitive from a vertebrate perspective, except perhaps for the Endangered African Wild Dog, which may be more prevalent here due to the proximity of the communal conservancies nearby.

Table 9. Priority reptile species with a description of the main threats these species experience.

Species	Common name	Project Site	Harvesting area	IUCN category	Endemic/Rare	Description of potential threats
Psammobates oculiferus	Serrated tent tortoise	Yes	Yes	Vulnerable[1]		Human-induced habitat alteration due to extensive agricultural development, overgrazing by domestic stock, droughts and wildfires, illegal collection of specimens for local subsistence consumption and for the pet trade (Alexander & Marais 2007). It is a protected species in Namibia.
Python natalensis	Southern African python	Yes	Yes	Vulnerable[1]		Rarity and high value in pet trade (Alexander & Marais 2007). It is a protected species in Namibia.
Varanus albigularis	Veld leguaan (monitor)	Yes	Yes	Vulnerable[1]		Illegal trade (skin and fat used as traditional medicine, leather) (Alexander & Marais 2007).
Psammophis jallae	Jalla's sand snake	Yes	Yes	Data Deficient		No specific threats are known.
Leptotyphlops labialis	Damara worm snake	Yes	Yes	Least concern	Endemic	Habitat is in soil under rocks or logs or old termite mounds (Alexander & Marais 2007). No specific threats are known.
Lygodactylus bradfieldi	Namibian dwarf gecko	Yes	Yes	Least concern	Endemic	May be found in trees, rocks or buildings (Alexander & Marais 2007). No specific threats are known.
Cordylus jordani	Namibian girdled lizard	No	Yes	Least concern	Endemic	Prefer rocky outcrops or other rocky areas (Alexander & Marais 2007). No specific threats are known.
Prosymna frontalis	Southwestern shovel-snout snake	No	Yes	Least concern	Endemic	Burrow in loose sand or found under rocks or logs or in termite mounds (Alexander & Marais 2007). No specific threats are known.
Psammophis leopardinus	Leopard whip snake	No	Yes	Least concern	Endemic	No specific threats are known.
Naja nigricollis nigricincta	Western barred spitting cobra, zebra snake	No	Yes	Least concern	Endemic (near)	No known threats.

[1] According to Griffin (2003)

Table 10. Mammal species of conservation concern with a description of the main threats these species experience.

Species	Common name	Project Site	Harvesting area	IUCN category	Threats
Diceros bicornis	Black Rhino	No	Yes	Critically Endangered	Black Rhinos are primarily threatened by illegal killing for horn.
Lycaon pictus	African Wild Dog	No	Yes	Endangered	Habitat fragmentation, human-wildlife conflict and transmission of infectious disease.
Acinonyx jubatus	Cheetah	Yes	Yes	Vulnerable	Habitat loss and fragmentation, conflict with livestock and game farmers and bush encroachment.
Equus zebra subsp. hartmannae	Hartmann's Mountain Zebra	No	Yes	Vulnerable, endemic	Farming activities, including fencing that prevent access to water.
Felis nigripes	Black-footed Cat	Yes	Yes	Vulnerable	Loss of den sites (need burrows of sympatric species) and a declining prey base due to human disturbances such as overgrazing and bush encroachment.
Giraffa camelopardalis	Giraffe	Yes	Yes	Vulnerable	Habitat loss, illegal hunting. Translocations of giraffe for tourism and consumptive use on private game ranches alleviate the situation currently to some extent.
Loxodonta africana	Elephant	No	Yes	Vulnerable	Loss and fragmentation of habitat caused by on-going human expansion, poaching for ivory and meat.
Panthera leo	Lion	No	Yes	Vulnerable	Human-wildlife conflict, indiscriminate killing and habitat loss.
Panthera pardus	Leopard	Yes	Yes	Vulnerable	Habitat fragmentation, reduced prey base and conflict with livestock and game farmers.
Smutsia temminckii	South African Pangolin	Yes	Yes	Vulnerable	Illegal trade in bushmeat, for medicinal purposes and superstitious value, electric fences.
Ceratotherium simum	White Rhino	No	Yes	Near Threatened	Poaching for the international rhino horn trade.
Equus quagga	Burchell's Zebra	No	Yes	Near Threatened	Plains Zebra are threatened by hunting elsewhere in Africa, but in Namibia zebra populations on freehold land increases. Plains zebra benefits from restored rangeland (Ben-Shahar 1992).
Hipposideros vittatus	Commerson's Leaf-nosed Bat	Yes	Yes	Near Threatened	Mining or disturbance of limestone caves and subsistence overhunting.
Parahyaena brunnea	Brown Hyena	Yes	Yes	Near Threatened	Human wildlife conflict (over 72% of livestock owners in Namibia believe that the Brown Hyenas is responsible for livestock losses (Lindsey et al. 2013), despite the finding that Brown Hyenas' very seldom prey on livestock).

Species	Common name	Project Site	Harvesting area	IUCN category	Threats
Elephantulus intufi	Bushveld Sengi	Yes	Yes	Least Concern, Endemic	Widespread and locally common. No specific threats are known.
Herpestes flavescens	Kaokoveld Slender Mongoose	No	Yes	Least Concern, Endemic	Habitat includes large granitic boulders and drainages and woodlands connecting rocky outcrops.
Petromus typicus	Dassie Rat	No	Yes	Least Concern, Endemic	Habitat is restricted to rocky mountainous areas, koppies and rocky outcrops. Distribution range includes only a very small portion of the south-western parts of the harvesting area.

7.10.3 Birds and invertebrates

For invertebrates the Otavi Mountain vegetation zone is expected to be the most sensitive due to the unique habitat it offers (SLR 2017). In a baseline invertebrate pitfall trap study, Irish (2018) concluded that no invertebrate biodiversity differences existed between sampling at the Project Site and a farm 60 km north of the Project Site, therefore the Project Site does not appear to be particularly sensitive from an invertebrate point of view.

In terms of bird sensitivity, both the Project Site and general harvesting area are sensitive (Scott & Scott 2018). Habitats in the harvesting area that are most sensitive include mountainous areas e.g. Otavi mountains, large ephemeral rivers and associated drainage lines (Scott & Scott 2018).

7.11 Savanna Ecology, with Specific Reference to the Dynamics of Bush Encroachment and Effects of Harvesting

7.11.1 What makes a savanna?

Savannas consist by definition of a continuous grass (herbaceous) layer interspersed with taller woody plants (Scholes & Archer 2003). The ratio of woody to herbaceous biomass is the dominant underlying structural[12] determinant of all savannas and is dynamic (inherently unstable) over time and space. The availability of soil water and nutrient resources (including CO_2) primarily controls (drives) savannas from the bottom up, while disturbances such as fire and herbivory (and bush harvesting) modify the effects of resource availability from the top down (Sankaran et al. 2004; 2005; 2008; Bond 2008). The relative importance of these driving forces changes with mean annual precipitation (MAP). On a broad scale, the percentage woody cover in African savannas (different from Australian savannas) is limited by mean annual precipitation up to about 650 mm pa (inset, Figure 17). Above that amount of precipitation, fire and herbivory become the main determinants of woody cover (Sankaran et al. 2005; Bond 2008). Savannas that occur in areas receiving <~540 mm pa (as the harvesting area does) is sometimes referred to as “stable” because they are mostly a function of MAP (Figure 17; Sankaran et al. 2005). In contrast, mesic savannas in regions receiving > ~780 mm pa are called “unstable”, in the sense that their structure is determined principally by disturbances such as fire and herbivory. Savannas in regions receiving between 540 mm and 780 mm are referred to as transitional – here the dynamics of vegetation and animal communities and populations in some years will share features with mesic savannas and in other years with arid savannas (Sankaran et al. 2005).

The tendency for an increase in woody cover is an entirely natural part of savanna ecosystems, and it is only limited (in natural situations) by opposing disturbances caused by factors such as fire. Consequently, the savanna ecosystem can take one of several forms, sometimes simultaneously,

[12] In the context of this study ‘savanna structure’ refers to the relative proportion of biomass apportioned in the woody or grass/herb layer, but also includes perspectives on the height distribution of woody plants in the vegetation. The savanna may thus be a specific type of woodland (e.g. open vs closed), but within that there may be one or more layers of woody plants that provide successively complex vertical structure. One of the characteristics of bush encroachment, apart from the high density of tree stems, is that there is very little vertical structural definition. On average, lower structural diversity equates with lower biological diversity for the simple reason that physical habitats are fewer.

depending on the balance of forces that swing the ratio either towards dominance by woody or by herbaceous species. In the semi-arid savannas extreme dominance by woody species is called bush encroachment or thicket formation; in the mesic savannas it could be closed woodland or even forest.

Savanna structure, which is drastically altered both by bush encroachment and harvesting, importantly controls ecosystem processes such as nutrient cycling, carbon sequestration patterns, forage quality and accessibility for herbivores, and micro habitat conditions for other organisms. It consequently controls the population sizes and composition of animal assemblages dependent on specific vegetation configurations for food and shelter (Scholes & Archer 1997; Sankaran et al. 2005; Gordon & Prins 2008), thus influencing biodiversity patterns in general. The ratio of trees to grasses also determines forage availability for browsing and grazing herbivores (and thus the relative abundances of grazers and browsers), and whether shelter is available or not. A number of antelope species depend critically on the appropriate ratio of shelter vs. open areas.

7.11.2 Why do we have so many bush encroached areas?

Bush encroachment is defined as the invasion and/or thickening of indigenous, aggressive, undesired woody species resulting in an imbalance of the grass: bush ratio and a concomitant reduction in grazing capacity (De Klerk 2004; Ward 2005). The ratio between woody and herbaceous plants further shape animal assemblages and habitats, thus biodiversity, and influences earth-atmosphere feedbacks (Scholes & Archer 1997; Sankaran et al. 2005). Bush encroachment also affects other ecological services to society negatively, including groundwater recharge, tourism, and biodiversity (Birch et al. 2016). Bush encroachment is therefore from society's perspective an undesirable state of savanna vegetation, although a natural process at the patch scale (Wiegand et al. 2006). Globally, there has been a trend towards increased woody cover and density in savannas and grasslands (Joubert 2014). In Namibia an estimated 45 million hectares are currently affected to some degree by bush encroachment (SAIEA 2016).

Bush encroachment has been recognized as a rangeland problem in southern African for almost a century (O'Connor et al. 2014). In Namibia the perception is that bush encroachment dramatically accelerated during the late 1950s and early 1960s (Bester 1996 in Joubert 2014). Nevertheless, landscape scale bush encroachment has been documented as early as the 1850s in Namibia (Anderson 1856 in Joubert 2014), which challenges the perception that it is only a recent phenomenon.

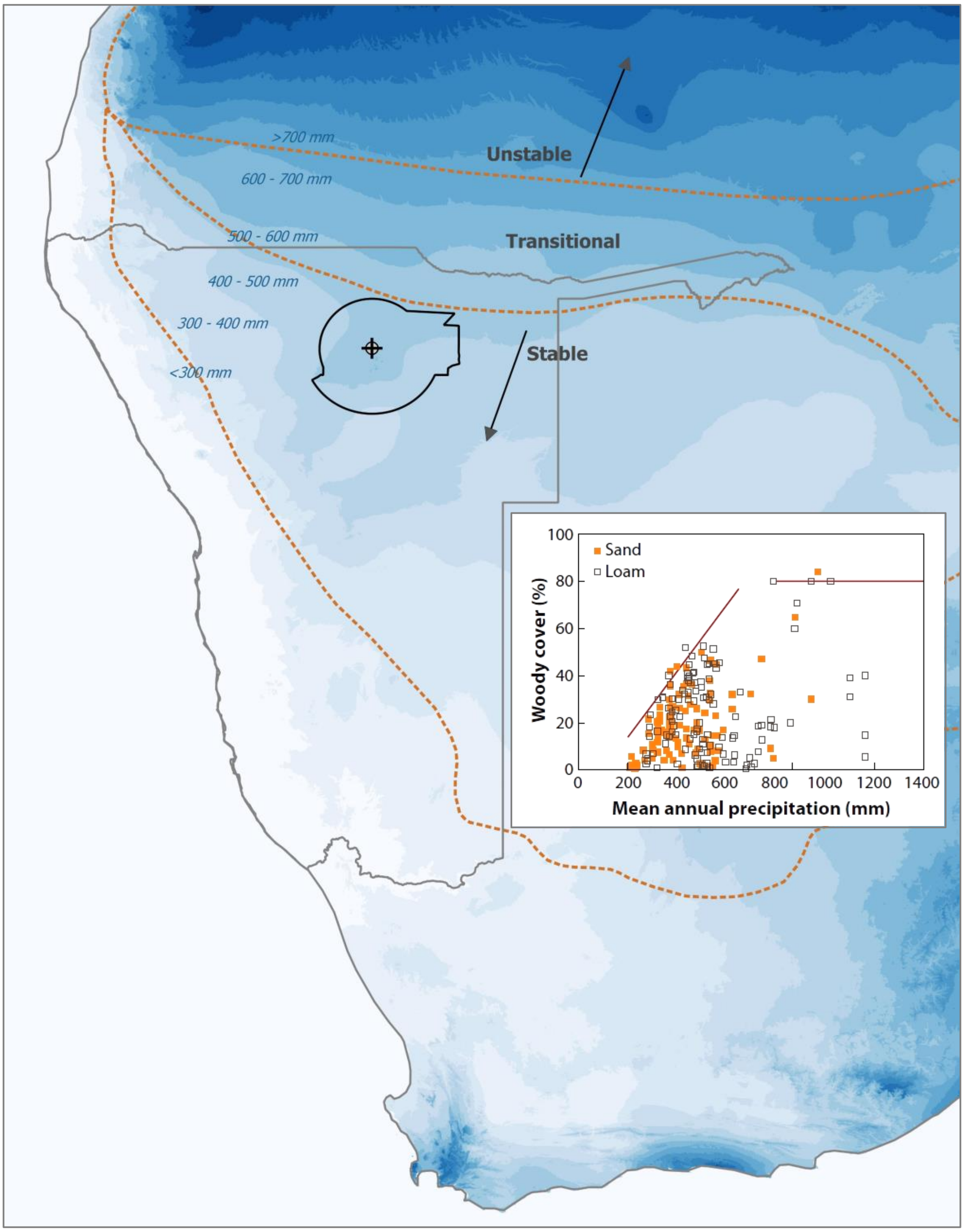

Figure 17. The location of the harvesting area relative to mean annual precipitation (MAP) in southern Africa.

The inset graph (reproduced from Bond 2008, with data from Sankaran et al. 2005) shows the way in which MAP limits percentage woody cover of African savannas, with an obvious inflection point above about 650 mm pa where disturbances such as fire and herbivory take over. Savannas are generally called stable (structure determined principally by MAP), unstable (structure determined principally by disturbances) or transitional (an arbitrary region in between stable and unstable) (Sankaran et al. 2005). The rough boundaries of these zones are shown as grey dotted lines on the map.

The ultimate causes and mechanisms by which woody plants dominate savanna systems are still debated, but recent continental and regional meta-analyses on these topics have increased our knowledge. It is now accepted that the woody layer is primarily regulated by the availability of resources such as water and nutrients (including CO_2), but modified by disturbances such as herbivory and fire (Sankaran et al. 2008). Other factors that have also been shown to regulate woody plants locally include water logging, frost and the removal of large trees, which may result in thickening of encroacher species (Joubert, 2014; Van Oudshoorn & Oosthuizen 2015).

A meta-analysis of the determinants of woody cover in African savannas revealed that the long-term mean annual precipitation was the strongest predictor of woody cover, followed by fire return period, soil characteristics and, lastly, herbivory (Sankaran et al. 2008). Woody cover was positively related to rainfall up to ~650mm/annum (Figure 17; Sankaran et al. 2008). Fires, on the other hand, reduced woody cover below the rainfall-determined maximum levels. Woody cover was also negatively correlated with clay content and soil nitrogen (N) availability. Elephants, mixed feeders and browsers negatively influenced woody cover, while grazers favoured woody vegetation when grazer biomass exceeded a certain threshold (Sankaran et al. 2008).

O'Connor et al. (2014) recently reviewed 23 southern African studies on bush encroachment. From this meta-analysis they proposed several drivers of bush encroachment, which they suggest interacted and the relative importance of which changed over time. They showed that the suppression of fire during the early twentieth century correlates largely with subsequent bush encroachment patterns. In support, fire suppression in fire exclusion experiments were shown to have an unequivocal influence on the increase of woody plants across savanna types ranging from 386 to 1300 mm per annum (O'Connor et al. 2014). While no studies came directly from the harvesting area, it seems reasonable to deduct that fire similarly affected bush encroachment in the harvesting area. Joubert et al. (2012), working in the central highlands near Windhoek, showed that fire increases seedling mortality significantly – consequently, when fire is suppressed at this critical stage, encroachment soon follows. O'Connor et al. (2014) showed that the rate of woody density change in fire-excluded plots was positively related to mean annual rainfall (although other factors such as soil type modified the relationship). Because annual rainfall in the harvesting area ranges widely (between ~360 to almost 600 mm pa), it is unlikely that the relationship with fire here will be simple. On average however, bush regrowth and recruitment following harvesting can be expected to occur at a faster rate in the higher rainfall areas of the harvesting area, i.e. north-eastern parts and Otavi Mountain areas compared to the comparatively lower rainfall in south-western parts of the harvesting area (Figure 4).

Grazing pressure is often invoked as a driver of bush encroachment and can either promote bush encroachment by reducing the fuel load for fires or by weakening grass competition with woody plants (De Klerk 2004; O'Connor et al. 2014). Long-term grazing experiments generally support the finding of a negative effect of heavy grazing on woody density, but a study at Otjiwarongo found that heavy grazing decreased woody density, while light grazing increased woody density (Van Niekerk (1980) in O'Connor et al. 2014). High grazing pressure (or other disturbances) in hydromorphic landscapes, such as dambos, can desiccate these areas by causing incisions in the landscape (e.g. gullies), with rapid colonization by woody plants (Pringle et al. 2011; O'Connor et al. 2014). Increasing global temperatures, however, may also be locally important where severe frost events frequently kill or retard woody plants, such as along drainage lines and omiramba. With warming temperatures, fewer frost events are likely and woody plants may encroach. In the study area, severe frost evidently top-killed expansive areas north of Tsumeb a few years ago[13]. Especially species such as *Terminalia prunioides* and *Dichrostachys cinerea* were affected.

The elimination of grazing can promote large fuel loads. O'Connor et al. (2014) postulated that the rinderpest epizootic of the 1890s temporarily reduced grazing pressure by killing a reported 95% of cattle herds and decimated ruminating wildlife, which subsequently resulted in an increased fire effect on woody plants. European farmers occupying the land in the early 1900s probably found vast open landscapes, which contrasted with some of the reports from the 1850s from explorers who described dense thickets in some areas (e.g. Anderson 1856 in Joubert 2014). The new administration looked unfavourably on the "wasteful fires", and as a response active suppression and regulations followed in the early 1900s. These were however only effective in the commercial areas. A similar chain of events is described for South Africa (O'Connor et al. 2014).

In the harvesting area, land tenure and land use have important repercussions for bush controlling factors, which could help to explain current bush encroachment patterns. The commercial livestock farming community has been very effective in suppressing fires (a small minority use fire as a bush control tool today) and mega-herbivores such as elephants were eliminated from these areas. The commercial farming areas (including the small-scale commercial areas) are generally the most encroached (C. van der Waal, personal observation) compared to communal areas and large protected areas. This differentiation between land tenure and land use has also been observed in other parts of southern Africa (O'Connor et al. 2014). In the national parks, fires (natural or controlled) still occur frequently and in the case of Etosha National Park an intact large herbivore assemblage, including mega-herbivores, interacts with fire to suppress woody plants. A striking difference in woody cover and structure is visible along the eastern boundary between Etosha National Park and the commercial farming areas (Figure 19). In contrast to the commercial areas, the frequency of fires, mostly anthropogenic, in the communal areas is higher but varies spatially (Figure 18) (Sheuyange et al. 2005) because fuel loads vary widely *inter alia* as a function of livestock stocking rates.

[13] Personal communication from a farmer in the Tsumeb area, Mr Leon Burger

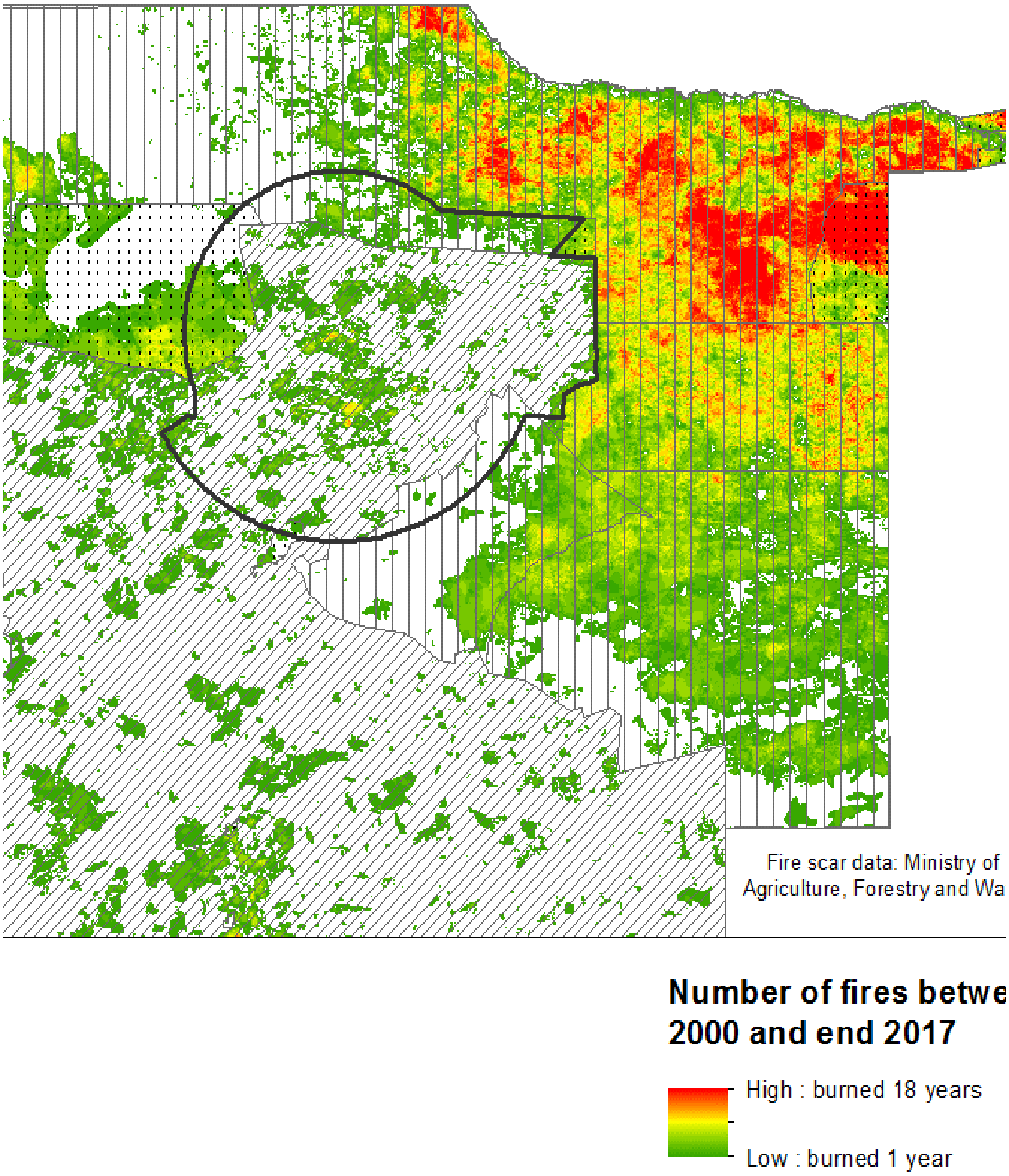

Figure 18 The frequency of annual fires since 2000 for the north-eastern parts of Namibia in relation to land tenure and land use differences.

In the commercial farmland areas (diagonal lines), fires are actively suppressed, which contrasts with state protected (dotted) and lightly stocked communal areas (vertical lines), where fires frequently occur. White background areas on the map had no detectable fires since 2000. The fire scar data are monitored via satellite by the Directorate of Forestry, MAWF.

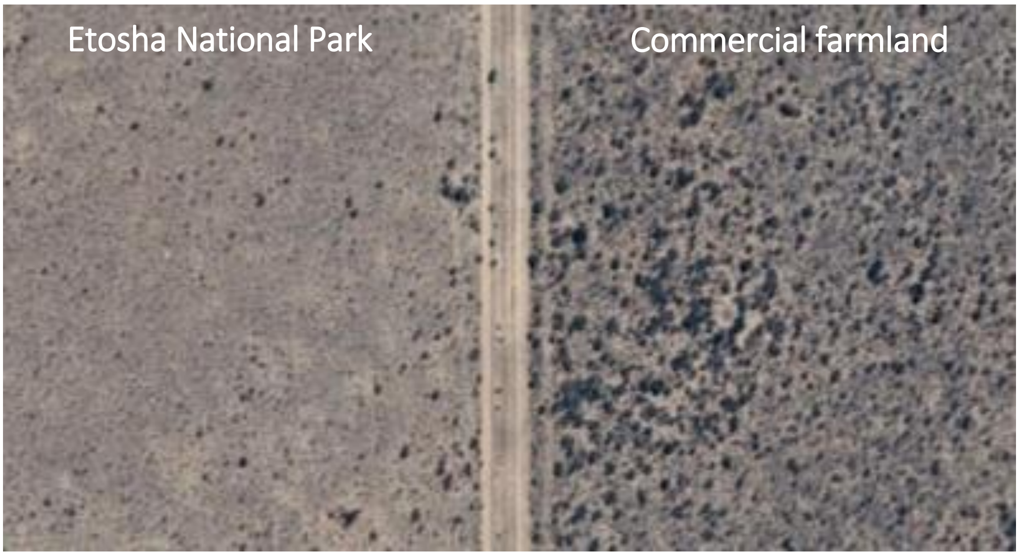

Figure 19. A Google Earth image (26 July 2016) from the north-western part of the harvesting area illustrating the differences in woody cover in Etosha National Park and commercial farmland.

Differences in fire, grazing and browsing regimes are proposed to have created this striking difference in woody cover.

Atmospheric CO_2 concentration has increased from a pre-industrial level of 277 ppm to 397 ppm in 2013 and is still increasing (O'Connor et al. 2014). Physiological understanding supported by experimental studies suggest that a rise in CO_2 benefits C_3 woody plants more than C_4 grasses (to our knowledge all grasses and woody plants in the harvesting area follow this pattern), hence might explain the recent bush encroachment thickening. The effect of CO_2 concentration on vegetation is difficult to study at a landscape scale and current evidence suggests that CO_2 may promote bush encroachment in mesic but not arid savannas (O'Connor et al. 2014). If true, bush encroachment may have been moderately promoted in the harvesting area to some extent by increasing atmospheric CO_2 concentrations, but only since the 1950-60s. The stimulating effect of high atmospheric CO_2 concentration on woody plants is expected to intensify as CO_2 concentrations increase in future.

The exact mechanisms by which bush encroachment is caused are, however, unclear (Ward 2005; Joubert 2014). Demographically, the relative abundance of woody plants in savannas is regulated at the seed, seedling or recruitment into taller size class phases (Bond & Midgley 2001). In semi-arid stable savannas (the harvesting area), where water is the most limiting factor, regulation is primarily during the phase where seedlings establish (Higgins et al. 2000; Sankaran et al. 2005). Once the vulnerable seedling phase has passed, established seedlings have a high probability of reaching maturity, thus contributing to the woody biomass at the cost of grasses (Higgins et al. 2000). Regulation at the seedling phase in arid savannas contrasts with regulation in mesic (high rainfall) savannas, where seedling establishment is generally not limited, but where fire or other disturbances such as large herbivores (e.g. elephants) prevent saplings from reaching mature size classes (Sankaran et al. 2005, Bond 2008). Here emerging woody plants only escape the suppressing fire-browse trap if these disturbances are suspended for a period. In the semi-arid study area, probably both regulation mechanisms, at the seed-seedling and sapling demographic stages, operate to some extent. For example, Joubert et al. (2008) proposed that consecutive above average rainfall seasons, a rare event, are required for the encroacher species *Acacia mellifera* to produce seed, germinate and for seedlings to establish. If a high density of seedlings survives, a bush encroached state develops over time. Fires that occur at the stage when the seedlings-saplings are susceptible have been experimentally shown to be effective in preventing this encroachment process in the Highland Savanna of Namibia (Joubert et al. 2012). Also, large trees often suppress recruitment within their root zone. When these large individuals are selectively removed, the release in competition results in an increase in woody density (Smit 2004).

In conclusion, while there is a natural tendency for an increase of woody density as a function of annual precipitation, the encroached state that exists in much of the harvesting area is thought to be mostly the result of human interference with natural feedback-type mechanisms such as fire, high spatial-temporal variation in herbivore density and the elimination of large herbivores such as elephant. Humans, particularly since the European colonial era, have suppressed fires, applied chronic grazing pressure, reduced browsers (especially mega-herbivores such as elephant), and to top it all have caused a global increase in atmospheric CO_2, which tend to favour woody plants above grasses.

Donaldson (1969) observed the following in recently settled South African (Northern Cape) commercial areas, which may well apply to the commercial farmland in the harvesting area: "*The sinking of boreholes, ring fencing of farms, the elimination of veld fires, together with the overutilization of the valuable grass species have, within a period of twenty years, swung the balance in favour of woody plants*".

Historical contingency factors have however also probably played a role in this. In Namibia a prolonged and severe drought in conjunction with an outbreak of foot-and-mouth disease, which prevented farmers from destocking their livestock on already depleted rangelands, causing overgrazing, may explain the rapid acceleration of bush encroachment after the 1960s in Namibia (Joubert 2014). This degradation of the grass layer followed in the wake of the rinderpest epizootic, a few decades earlier, which reduced grazer populations and facilitated frequent, intense fires, presumably creating open savannas in much of the harvesting area. In addition, in the 1970s an estimated 4 million large indigenous trees, mainly tamboti (*Spirostachys africana*), were cut to supply props for the Tsumeb and Abenab mines and allowing the rapid encroachment of species such as *Dichrostachys cinerea* and *Acacia mellifera* (Le Roux et al. 2009).

7.11.3 The effects of harvesting woody biomass on species and populations

In this section we both report on a pilot study that we had conducted for the current report, wherein we surveyed harvested and un-harvested (control) areas for a number of variables related to community structure and composition, and we summarise findings from other workers as well as the general ecological literature.

Vegetation responses to woody biomass removal

One of the perceived advantages of reversing bush encroachment is the expected increase in herbaceous biomass (SLR 2017). Our results confirm that herbaceous biomass increases after woody plant harvesting, but that aftercare is required to sustain a high herbaceous production over longer time frames (Appendix 7). Without aftercare, woody biomass especially leaf mass), hence competition between woody and herbaceous plants, increases over time and thereby suppressing the herbaceous biomass again, which may result in a worse ecological state than before (Figure 20).

Figure 20. Vigorous regrowth of Dichrostachys cinerea *at the Ohorongo site following biomass harvesting, presumably without any aftercare. There is virtually no grass and very low plant species diversity (Photo: C. van der Waal).*

Our finding that woody density in the lowest 0-0.5 m height class was higher in harvested areas than bush encroached controls is important. This height class represents mainly seedlings and saplings but may also have included root suckers from species that reproduce vegetatively. This highlights the importance of aftercare to prevent a transition back to a thickened woody state, although such a transition will also depend on the type, scale and intensity of the harvesting process. The higher woody density in harvested areas is probably a combination of a release of between-plant competition (both woody and herbaceous biomass decreased), combined with the establishment opportunity created by the mechanical disturbance of the soil surface (SAIEA 2016) and the suite of characteristics such as fast recruitment and rapid-growth that characterize encroacher species. It is likely that the woody species composition without aftercare will increasingly shift toward dominance of encroacher species, because of their ability to exploit disturbances such as those created by the harvesting process.

A gradual thinning of woody plants, staggered over several seasons rather than a single drastic thinning event may stabilize the woody component to some degree (Smit 2004; Smit et al. 2015), lessening the need for intensive aftercare.

Microbial responses to biomass removal
Bush harvesting apparently affects the status of soil microbes. In a study at CCF (Otjiwarongo district) soil microbial biomass, the biomass of specific taxonomic groups and overall microbial community structure was studied in harvested vs. control areas (Buyer et al. 2016). Bush harvesting altered the microbial community structure compared to control plots, but the magnitude of this perturbation gradually declined with time and over a time span of 3-9 years were similar to the encroached control plots (Buyer et al. 2016). Buyer et al. (2016) suggested that the microbial changes were primarily driven by pH, Carbon (C), and Nitrogen (N), which was higher under bushes than in grassy areas. A loss in nutrients due to biomass harvesting therefore decrease microbial biomass and change the community structure of microbial communities, which appear to recover over a 3-9 year period. In this study, recovery appeared to be more complete for Bacteria and Archaea than fungal communities.

Invertebrate responses to biomass removal
Irish (2018) compared invertebrate biodiversity in cleared vs. encroached areas at two sites in the harvesting area. At both sites biodiversity (Shannon index) was higher, species evenness higher and species dominance lower in cleared areas than encroached control areas, suggesting that partial bush clearing enhances invertebrate diversity and results in a healthier invertebrate community structure. In the Southern Kalahari, species richness of grasshoppers declined with increasing shrub cover while spiders and beetles exhibited a bell-shaped response to shrub cover with species richness reaching a peak at intermediate shrub cover values (12 and 18% woody cover) (Hoffmann et al. 2010). Structurally complex habitats (intermediate woody density) provide more niches and environmental resources and thus increase species diversity for these organisms (Hoffmann et al. 2010). Total clearing is therefore expected to negatively affect invertebrate diversity (Irish 2018).

Bird responses to woody biomass removal
Bird assemblages respond to changes in vegetation structure (Sirami et al. 2009). In a South African study, bird species richness peaked at intermediate bush densities with the loss of certain open-habitat species in dense bush areas (Sirami et al. 2009). Although, large-scale bush encroachment is perceived to have mostly negative effects overall, a patchy distribution of bush clumps in open savanna offer habitat for specialised species, thereby increasing the biodiversity of an area. In a recent BIOTA study in Namibia bird species-richness was compared between bush thickets and two alternative habitats (dry drainage lines and open grassy areas), across a 257 mm/year rainfall gradient. The results suggest that differences between bird assemblages were influenced more by differences in the habitats, which differed in woody structure, than the aridity gradient. Across the aridity gradient thickets lost the most species with increasing aridity, while drainage lines retain high species richness despite the aridity gradient (Hoffman et al. 2010).

However, thickets can take many forms, and birds will respond differently to the removal of different components of the thicket. Removal of the large trees will specifically affect species such as large raptors, vultures and Sociable Weavers (*Philetarius socius*) that require nesting and perching sites (Scott & Scott 2018). More frugivorous bird species and individuals also make use of mature rather than sapling or dead trees (Dean et al. 1999). On the other hand, a number of smaller passerines have specialised on the more complex vertical structure of smaller thicket trees. These include species such as the Yellow-bellied Eremomela (*Eremomela icteropygialis*), Long-billed Crombec (*Sylvietta rufescens*). Species such as the Southern Pied Babbler (*Turdoides bicolor*) includes *A. mellifera* thickets in their habitat requirements and others, such as the Chestnut-vented Tit-Babbler (*Parisoma subcaeruleum*) prefer the ecotone between thickets and more open woodland. At the very least the removal of woody biomass will result in a significant change in species composition as these woody thicket species are replaced by species more characteristic of open woodland and shrubland.

Other vertebrate responses to woody biomass removal

The clearing of encroacher bush changes the habitat conditions for organisms. Bush harvesting may have both positive and negative effects depending on the species group, the spatial scale that is considered and the severity of shrub encroachment or clearing (Tews et al. 2004). Changes in the structural diversity of the landscape (horizontally and vertically) may influence animal diversity directly, as well as indirectly (Tews et al. 2004). For large herbivores, the grazer guild is expected to benefit from bush harvesting through an increase in herbaceous production (Ben-Shahar 1992), while the browser guild is expected to decrease in abundance, due to potential browse loss. A bush clearing experiment in the Lowveld savanna of South African showed that Burchell's zebra and blue wildebeest preferred the cleared areas, while impala and kudu showed no preference (Ben-Shahar 1992). Herbivore species depending on sight for predator detection may also benefit from a more open structure. Our field experiment also found a higher grazer dung pile and lower browser dung pile density in the harvested areas, compared to the paired encroached (control) areas nearby. This suggests that grazers spend more time in the open, harvested areas, while browsers avoided harvested areas. Severely encroached bush, however, offer little forage for browsers due to inaccessibility and shortened leaf carriage of dense deciduous species (Smit 2001).

The effect of bush harvesting on small mammal populations is less clear. Shrubby vegetation structures play an important role for the yellow mongoose, *Cynictis penicillata*, a small carnivore species expected in the study area (Blaum et al. 2007b). Interestingly, the effects of shrubs on this species are inconsistent across different spatial scales. Yellow mongooses were found to build their reproduction dens preferably under large shrub structures, which provide additional shelter against avian nest predators and effectively protect burrow systems from collapsing under hoof trampling by large herbivores. Whereas the impacts of larger shrub patches are positive at the micro-habitat scale, an increase in shrub density at larger spatial scales, i.e., home range areas, affects group size and reproduction success negatively, probably because of an indirect effect of decreased prey abundance (i.e., rodents and insects) for the yellow mongooses (Blaum et al. 2007b). Blaum et al. (2007a) found that rodent diversity showed a unimodal (hump-shaped) response pattern with increasing shrub cover. Maximum rodent diversity was found at a medium cover (12.5%) of shrubby vegetation, but declined at very sparse and very dense shrub cover, but only at a relatively large 250 ha scale. At the smaller home-range scale no pattern emerged, which probably explains why a study at the Neudamm Agricultural Farm, Khomas region, trapping in bush encroached (>1000 encroacher bushes/ha) and adjacent open savanna areas, failed to find differences between sites in terms of abundance, diversity or species composition of small mammals, although low numbers of two species were only captured in the open habitat (Karuaera 2011).

One exception appears to be the black-tailed tree rat, *Thallomys nigricauda* (expected in the harvesting area). An increase of shrub density improves habitat conditions for the tree rat due to a better connectivity among suitable structures for food and mates (Eccard & Ylönen 2003). However, for reproduction purposes this species depends on large dead trees with cavities and hollows for nesting. In areas where dead trees are harvested, suitable nesting trees might become a limiting factor for the viability of local tree rat populations (Tews et al. 2004).

Reptiles are expected to decline with bush encroachment, thus should benefit from bush harvesting. A study on the effects of bush encroachment on lizard diversity in central Namibia, indicated that most lizard species declined in dense bush habitats, except for one species that were observed in larger numbers in bush encroached areas (Meik et al. 2002). Arboreal lizard species, however, does not always benefit form bush encroachment, as these species are often associated with particular tree species, for example *Acacia erioloba*, because of the flaky, loose bark structure which offers cover and abundant invertebrate prey (Meik et al. 2002). Invasive woody species including *Dichrostachys cinerea* and *A. mellifera* are characterized by smoother bark (Tews et al. 2004).

Whether specialist organisms re-colonize new open habitat, will be a function of the presence of remnants of these species, as well as obstacles to immigration where these species are locally extinct. Founder effects may also occur where competing species have similar niche preferences.

In conclusion, selective bush harvesting of encroached areas should improve the diversity and abundance of animals, provided that no dispersal or population regulation restrictions prohibit low density or locally extinct species to inhabit the newly created habitat. How the open structure created by harvesting is maintained, will determine how long these perceived benefits last.

8 Integrated Discussion

In this discussion we first deal with the elephant in the room: if the project was funded because it can potentially restore savanna integrity and not because Namibia needs electricity and there happens to be a good resource that can be utilized for such a purpose, it is very important that the ecological and management implications are understood by all stakeholders.

Secondly, we discuss the importance of avoiding impacts to species of conservation concern, followed by a discussion of sensitive areas integrated across all taxa and a discussion of critical knowledge gaps.

8.1 The ecological goal is a significant reduction of woody biomass, not maximum woody yield (bush farming)

Existing knowledge and evidence suggest that the region encompassed by the proposed harvesting area is indeed encroached by several species, with prominent species being sickle bush (*Dichrostachys cinerea*), black thorn/swarthaak (*Acacia mellifera*) and mopane (*Colophospermum mopane*) (Figure 25A). It also seems, from previous rough estimates, that the density of encroacher species is relatively high in the proposed harvesting area (which is also the stronghold of sickle bush) (Figure 25B). Although these estimates are old (both maps date from the mid-90s [Bester 1996; 1998]) and were based almost entirely on expert knowledge, they are still considered to accurately reflect the region's status at a coarse scale. Hence it is perhaps self-evident that the rangelands in this region are widely agreed to be degraded. Degradation occurs from both a biodiversity and agricultural perspective because of the homogenisation of habitats and loss of the productivity of the grass layer, respectively.

Utilising the woody biomass for energy production seems like a logical and sensible way to address two different aspects: contributing to Namibia's goal to become self-sufficient in energy production while simultaneously improving agricultural production through the improvement of rangeland condition. The proposed biomass power project therefore occurs within this context of rangeland dynamics, with an underlying implicit goal of restoration of savanna structure, function and composition.

"Improvement of rangelands" is nothing more than the restoration of the ecological structure, function and composition (SFC) of the dryland savannas that make up the bulk of Namibia's rangelands. This includes emergent properties such as resilience (the ability to bounce back after a disturbance) and primary productivity (a measure of the ecosystem's ability to transform sunlight and nutrients into biomass). There might be some argument about the optimal ratio of woody to herbaceous/grass plants that constitutes an improved rangeland but there should be no argument about the veracity of the statement that a resilient and productive savanna will also be the one that has the highest level of biological integrity, even if productivity is measured in the relatively narrow definition of grass- and herb-layer production.

To realize the secondary goal of the Biomass Power Project to restore savanna structure and function, harvesting of woody re-growth (also called bush or wood farming) should be discouraged (SAIEA 2016). Allowing a harvested area to intentionally re-thicken to sustain repeated bush harvesting in future will compromise the expected positive impacts on ecosystem services such as rangeland productivity, biodiversity and water recharge. This should not be confused with a gradual thinning process where the same land (but not regrowth) is repeatedly harvested at low intensity over consecutive seasons as proposed by Smit (2004).

In defining the baseline and in assessing potential impacts and their significance, the risk that the restoration goal will not be reached therefore has to weigh heavily. The results of all the specialist studies in the current project, as well as numerous published and unpublished reports suggest that simple removal of the woody layer is unlikely to achieve an improvement in savanna condition over the longer term (i.e. more than 5 years after harvesting). More importantly, even where certain aspects do improve (e.g. a more productive grassland is created for increased livestock production), it is unlikely that this will be stable or sustainable because there is a strong tendency for subsequent thicket formation and for unpalatable or only annual grass-layer species to colonise cleared areas. Two harvesting effects studies completed for the current project (Appendix 7 [hereafter HES] and Irish 2018) both suggest that there is devil in the detail. The HES found that herbaceous biomass increases after harvesting, but the increase is only significant where harvested areas are maintained in an open state afterwards (Figure 21A). More importantly, the density of juvenile woody plants (height classes below 1 m) increases significantly after harvesting, unless it is actively removed (Figure 21C), emphasising the tendency for thicket formation regardless of the geographic location of the study site. Overall herbivore presence was not affected by harvesting, but the study sites differed markedly, and the different feeding guilds responded significantly to harvesting with browsers dominating in thicket (control) areas, grazers in harvested and maintained areas and mixed feeders in harvested areas (Figure 21B). This suggests that bush clearing can have beneficial effects for certain guilds but negative effects for others. Invertebrate diversity and evenness increased and dominance decreased after bush clearing, suggesting an improvement in community (taxon) structure after harvesting (Irish 2018). However, the differences were relatively small and without replication of the sampling units it could not be determined whether these changes were significant.

It should be clear that it matters greatly how the ecological restoration goal is formulated. Ecological restoration is itself defined as the assisted recovery of ecosystem structure, function and composition[14] (SFC) and implies that we know the recovery state's SFC.

The long history of encroachment means that there is little that exists currently to use as a reference for an intact savanna and one will have to fall back on generic principles of the theory of ecosystem dynamics while simultaneously cobbling together a picture of a healthy savanna from historical descriptions and geographically isolated remnant habitats. This is a problem, but it is perhaps easier to view it in terms of state and transition dynamics. At least it will be relatively easy to define what it should not look like, and if it is assumed that the undesired states are extreme versions that exist along one or more axes of state-change, it becomes simpler to define the remaining conditions, i.e. the desired state/s. Regardless of the detail, **it is important that this definition of the desired state is a negotiated one that is accepted by all stakeholders, and especially by the funders and implementers of the project**.

[14] These three aspects respectively refer to the diversity of species, the cycling of nutrients and energy through the ecosystem and the identity of species that occur there.

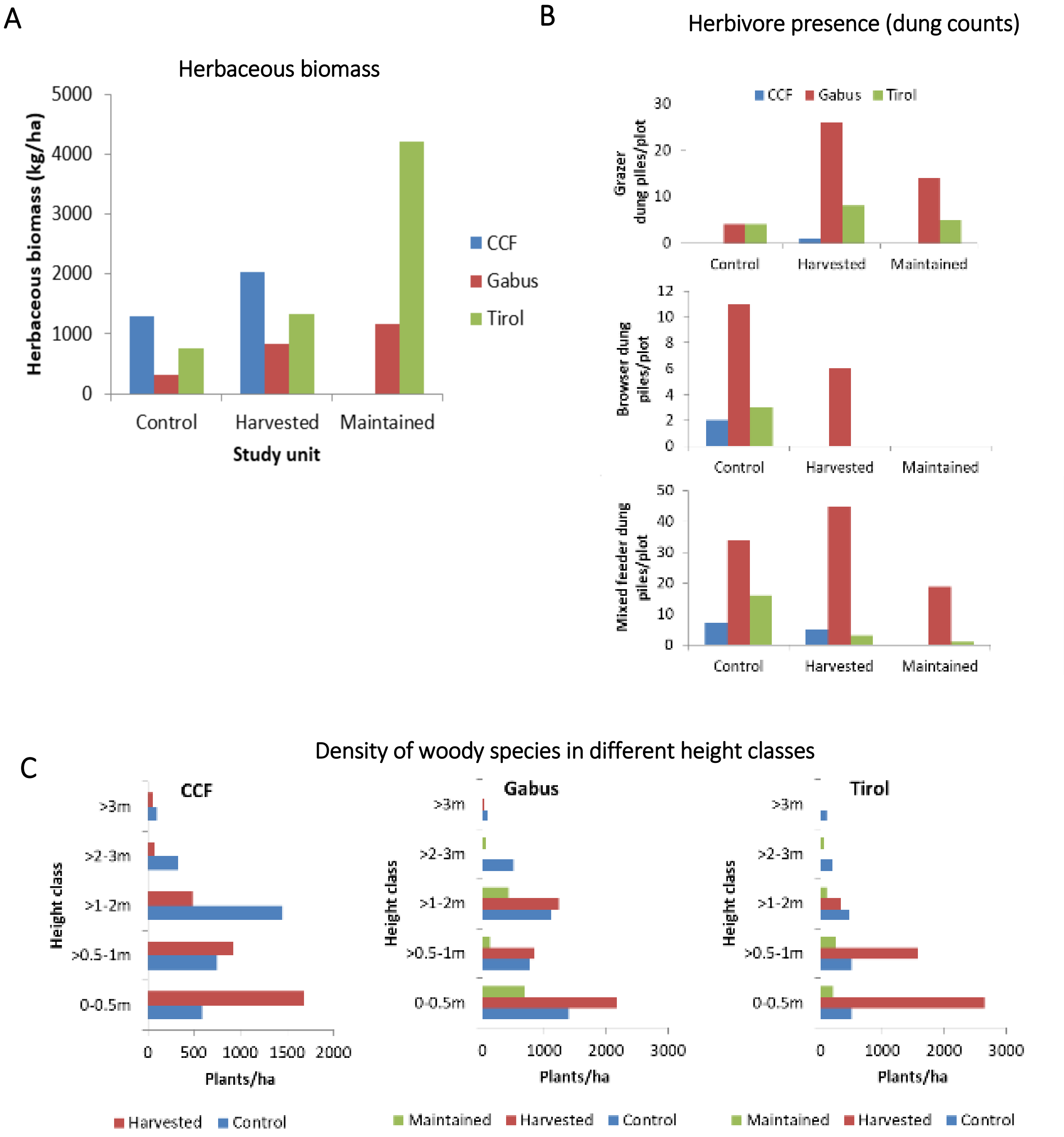

Figure 21. Summary of findings from the harvesting effects study (Appendix 7). A) A comparison of the herbaceous biomass between study units and treatments. B) Comparison of dung pile densities between treatments per study units for grazers (top), browsers (middle) and mixed feeders (bottom). C) Comparison of treatments in the various study units in terms of the density of woody plants in different height classes.

"Maintained" refers to sites where the biomass was harvested, and the site then actively maintained in an open state removing subsequent woody growth. The three study sites were the farms Gabus and Tirol, and the properties of the Cheetah Conservation Foundation (CCF) near Otjiwarongo (see Figure 2). These differed in terms of vegetation types, dominant species and harvesting treatments (see Appendix 7 for more detail).

To ensure that the restoration goal is achieved, **clearly defined central accountability and management as well as a strong organising framework that includes incentives for responsible management, training of role players and guidance based on data collected through specific research and monitoring will be important aspects to consider.** We make some recommendations in this regard in Section C13 on management and mitigation of impacts.

8.2 Sensitivity and No-Go zones across all taxa

Biodiversity sensitivity is a fluid concept, without a precise definition that holds across all levels of ecological organisation from populations to ecosystems. Nevertheless, a few general concepts have emerged across all specialist studies. First, in terms of environmental management, it makes most sense to view sensitivity as a property of a habitat or a place, not so much of species (although a specific species might be sensitive to disturbance, it will ultimately contribute to the level of sensitivity of a place or a zone because that is where an activity will take place or can be avoided). Second, there are various criteria that relate to the presence and abundance of species of conservation concern (all aspects of rarity, endemicity and threats) and/or to the resilience of a habitat or ecosystem. The latter refers inter alia to the likelihood of recovery after a disturbance. Furthermore, if a habitat or ecosystem is functionally important, contributing disproportionately to total ecosystem services (e.g. a habitat containing many large camel thorn trees potentially provides important nest sites for endangered vultures), it can be viewed as rare or critical to the continued functioning of other habitats or species and are thus sensitive. For the highly mobile birds, the proximity of the study area to protected areas additionally played a role in deciding sensitivity (Scott & Scott 2018), as did the proximity of the study area to centres of endemism for invertebrates (SLR 2017; Irish 2018). Following established practice, where different specialists provided different sensitivity ratings[15], the highest (most sensitive) rating is taken for each habitat.

The rest of this discussion refers to Figure 22.

8.2.1 No-go zones

No-go means that these areas are recommended to be excluded from any harvesting activities and are similar to the Critical Habitat of the IFC's 6 Standard and the FSC's High Conservation Value Areas. Clear geographic distinctions have emerged in terms of overall sensitivity in the study area, with especially the No-go areas being relatively clearly defined. First on this list is the Otavi Mountains. For many reasons, some of the areas in the harvesting zone have become strongholds of rare, threatened or endangered plant species. The rocky slopes of Otavi Mountains and other rocky outcrops are good examples of such species refuges that support high diversity and tend to support more endemic species of all taxa investigated. This includes all slopes, rocky or otherwise, that are steeper than 12.5% (Pallett & Tarr 2017). Many of these habitats are too small to depict on a map at the scale of the study area (Figure 22), so the principle will have to be included into the EMP and implemented at

[15] Scott & Scott (2018) had a rating system of only sensitive or not sensitive, while Irish did not provide an explicit habitat-based sensitivity rating. In the former case we considered "sensitive" to mean the same as our "Very sensitive". For invertebrates, where habitats are normally much simpler than for other taxa, we assumed that the combined vegetation and vertebrate sensitivities would be adequate to cover invertebrate threats.

project level. These areas should be treated with care and their No-go status rigorously enforced to ensure that their high biodiversity value and underlying attributes are not compromised (IFC 2012).

Two dambos towards the northern half of the harvesting area appear to be unique habitats and support a complement of species that do not occur elsewhere. They are similarly considered No-go, albeit for somewhat different reasons. The omuramba associated with these two dambos is probably not only important ephemeral riverine habitat, but also supports the function or process of water transport and supply that will maintain species both on its fringe and in the adjacent dambos. Closely related to this aspect, all drainage lines are No-go zones, both because this is a key recommendation in the SEA (SAIEA 2016) and Harvesting Guidelines (Pallet & Tarr 2017) and because their loss will have a disproportionate impact on almost all organisms. Related to this, all other water features such as springs, other omiramba, pans and wetlands (even if they are ephemeral) are also rated as No-go. For the birds (and amphibians) all pan habitats and their fringes were rated as sensitive by Scott & Scott (2018), but for consistency’s sake we upgrade this rating to No-go.

The following additional areas are also No-go due to the high probability that biomass harvesting or related activities could negatively affect individuals, populations or ecological processes and attributes of a specific area:

- All formal protected areas. We furthermore suggest that this should include a buffer zone of about two farms wide around the Etosha and Waterberg National Parks, to decrease the risk of poaching, particularly the critically important black rhino.
- All known locations where populations of very rare plants occur (Figure 15).
- As point features, special breeding and nesting sites of any threatened species, e.g. raptors and vultures (Scott & Scott 2018). In this regard, emphasis should be placed on riverine fringes and any other areas that support large trees (see also above).

All No-go areas should be treated with care and their No-go status rigorously enforced to ensure that their high biodiversity value and underlying attributes are not compromised (IFC 2012, FSC High Conservation Value Areas). As a starting point all No-go areas should be identified and mapped at a local scale in the site-specific management plans.

8.2.2 Very sensitive

The area surrounding the rocky slopes of the Otavi Mountains is considered here to be functionally closely integrated into the mountain itself, hence we view this all as one ecosystem and rate it as Very sensitive. This does not preclude harvesting but does require a more robust assessment of impacts per harvesting site and a more rigorous application of harvesting guidelines and of monitoring. A similar approach is prescribed for the other Very sensitive area, the good quality woodland in the east of the harvesting area. Here the sensitive handling of large trees of all the indicated species and clusters of intact woodland will be very important.

Ephemeral rivers and drainage lines are regarded as very sensitive[16] habitats in terms of birds, with large trees and bush that provide habitat for perching, roosting, foraging and nesting (the latter is especially important for vultures and other raptors, as well as for cavity breeders) (Scott & Scott 2018). Watercourses may also serve as movement corridors for birds, including migrant species and bird diversity is likely to increase for the short periods that the rivers do hold water. The routes of new power lines to and from the Project Site are considered to be very sensitive zones for birds because of the risk of collision and electrocution.

8.2.3 Sensitive

The Karstveld was rated as Sensitive mainly because it supports high numbers of species of conservation concern, species that are at future risk and many large trees, and the zone has undergone historical bush control using arboricides[17] and has low recovery potential. The seemingly indiscriminate application of arboricides has had detrimental effects on protected and non-target species in these areas (see section 17.6 "After harvest: preventing woody regrowth to achieve grass-layer productivity" for a discussion of arboricide best practises). It is therefore particularly important to conserve what is left. The northern dune fields are also Sensitive because of the presence of large trees of several typical species. Other than their botanical properties, there are no criteria for ranking these zones.

8.2.4 Least sensitive

The thornbush and mopane savannas are both Least sensitive. The rest of the Kalahari woodland/tree savanna zone is Least sensitive in previously degraded areas but large specimens of several typical woodland trees occur scattered throughout – these should be treated as Sensitive, particularly where their population density is high. Other than their botanical properties, there are no criteria for ranking these zones.

[16] Scott & Scott (2018) rated this as sensitive, but they had only two categories of sensitivity and we interpreted their 'sensitive' rating as equivalent to our 'very sensitive'.

[17] Mr Leon Burger, a farmer in the area, reports a large-scale die-off as a result of frost some years ago (pers. comm.). At this stage it is not possible to distinguish between mortality as a result of frost (a natural factor) and arboricide.

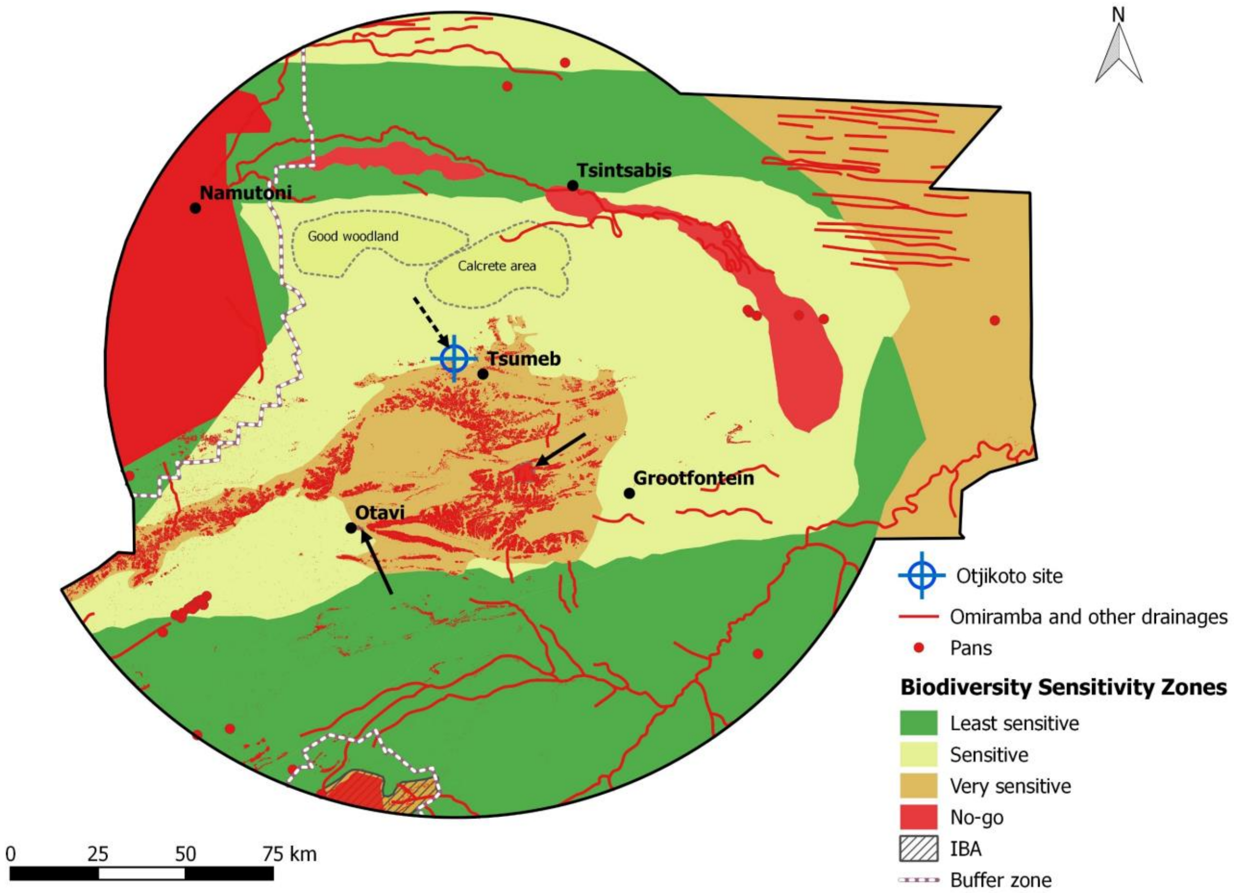

Figure 22. Biodiversity sensitivity zones in the harvesting area, combined across all taxa and including general guidelines.

The black arrows point to two special plant species zones; refer to Figure 15 for more detail. The black dotted arrow points to the location of new transmission lines at the planned Otjikoto Project Site – these lines represent a zone that is considered here to be Very sensitive because of the presence of several bird species that are prone to collisions and electrocutions (Scott & Scott 2018, p22). The Important Bird Area (IBA) that surrounds the Waterberg Park in the south should also be considered as Very sensitive. For the Otavi Mountain and rocky outcrops No-go zone: note that many of the slopes > 12.5% are often too small to depict at this scale. As such this map is only a broad guideline as a first-level reference. Additionally, it should always be read in conjunction with the narrative description for more detail. The proposed buffers around the national parks are roughly 1 – 2 farms wide and will become No-go areas if accepted.

8.2.5 Natural, modified and critical habitats

According to the IFC's Standard 6 a habitat is defined as a terrestrial, freshwater, or marine geographical unit or airway that supports assemblages of living organisms and their interactions with the non-living environment. For the purposes of implementation of this Performance Standard, habitats are divided into modified, natural, and critical. Critical habitats are a subset of modified or natural habitats.

Applied to the study area natural habitats are areas composed of viable assemblages of plant and animal species of native origin, and where human activity has not essentially modified an area's primary ecological functions and species composition. In the study area the legally protected national parks were classified as Natural habitat (Figure 23).

Modified habitats are areas that may contain a large proportion of plant and animal species of non-native origin, and where human activity has substantially modified an area's primary ecological functioning and species composition. We argue that most of the communal and commercial farmland has been modified to some degree by introduction of livestock (cattle, sheep and goats) and conversion to crop fields, while ecological factors such as natural fires has been altered (section 7.11.3). Virtually the entire farmland area has experienced species compositional changes affecting both the vegetation (bush encroachment and related vegetation changes) and changes in large animal assemblages (extermination of large, native herbivores and predators; section 7.11.3). Some grey areas exist, however, such as game ranches and communal areas with very low human and livestock densities that may functionally approach the Natural habitat category.

Critical habitats are areas with high biodiversity value, including habitat of significant importance to critically endangered and endangered species, habitat of significant importance to endemic and restricted-range species highly threatened or unique ecosystems (IFC 2012). In the study area these coincide with the No-go zones as delineated in Section 8.2.1 (Figure 22).

For managing the potential impacts of biomass harvesting and processing in the study area, we propose that the biodiversity sensitivity zones (Figure 22) provides a more practical framework. The sensitivity zones provide more spatial details (i.e. least, sensitive and very sensitive zones) relevant to managing harvesting impacts (compare Figure 22 with Figure 23).

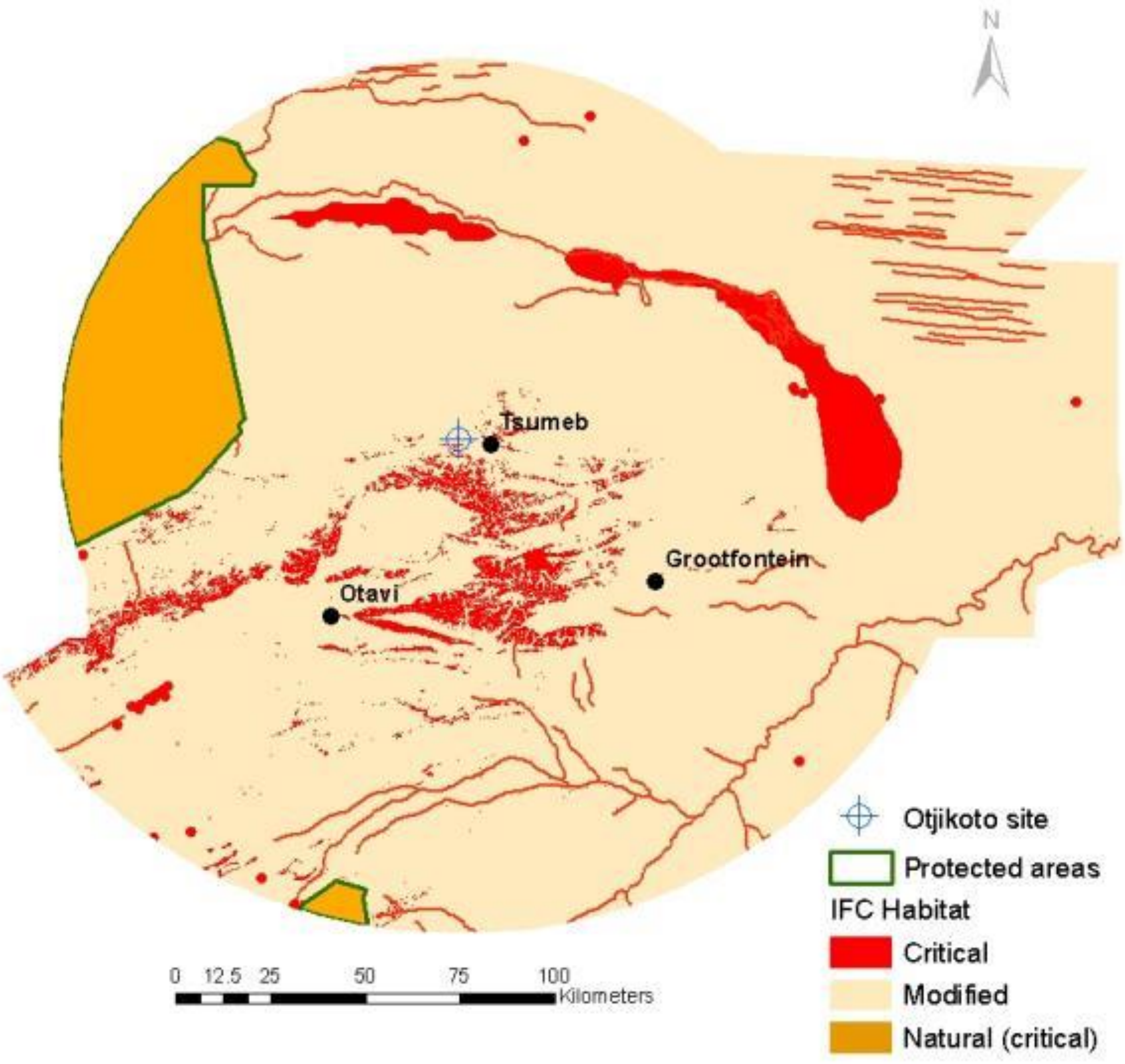

Figure 23 Natural, modified and Critical habitats as defined by the IFC's Standard 6 Biodiversity Conservation and Sustainable Management of Living Natural Resources.

Natural habitats are those preserved in the legally protected National Parks. In the study area all farmland was classified as Modified habitat, while all the biodiversity No-go sensitivity zones and areas were classified as Critical habitat. Critical habitats include rocky and mountainous areas, drainage lines, dambos and pans, as well as specific areas where very rare plant species occur.

8.3 Knowledge gaps and the need to fill them

8.3.1 The risk of not knowing enough

Where knowledge is poor, there is (or should be) a systematic bias to rate a potential impact of higher significance to insure against the uncertainty, often leading to costly restrictions on utilisations. In addition, the adaptive management approach requires a solid foundational area-specific baseline understanding of the system's dynamics for appropriate evaluation of monitoring data and to enable informed decision-making. Knowledge gaps therefore pose a risk to the project itself, because it may lock out certain areas from utilisation, or impose costly restrictions in others. It stands to reason that it is in the best interest of the project proponent to fill critical knowledge gaps as soon as possible, with the main objective being to clear up uncertainties in the impact assessment itself and thus be able to draft a smarter and more cost-efficient environmental management plan.

8.3.2 Critical knowledge gaps

The most important knowledge gaps for the current project are all related to the refinement of current understanding that tends to be at a generic or coarse scale only, or has received little attention before. For instance, the existing maps of the distribution of encroachment is now more than two decades old and the most recent improvement exists only at the national scale. Working without a good idea where the resource is located and what affects its distribution is a recipe for failure. Hence, this is a critical gap that needs to be filled. Further knowledge gaps all relate to management: a better understanding is needed of the effects of harvesting on both ecological integrity and productivity, a better, more clearly resolved definition is required of the desired end-state, and indicators for monitoring of success should be identified and calibrated.

We suggest that the following studies are considered and initiated synchronous with the first operational harvesting operations. As new knowledge from these studies and monitoring accumulate, these are incorporated in management and training plans in an adaptive management framework.

1. An understanding of the distribution and density of encroaching species at the appropriate scale

This is a high priority study ("must-have") and it would be advantageous if this is implemented relatively early on to aid with selecting high resource areas[18]. Encroachment is not a spatially uniform phenomenon. However, the only national-scale assessments of the distribution of encroacher species and their density that exist currently are more than 20 years old and based on expert opinion and experience (Figure 25A and B). By their own admission, even the recent SEA on encroacher bush harvesting (SAIEA 2016) have improved this situation only marginally (Figure 24) and have suggested that higher resolution spatial estimates should be made at the level of specific projects.

A better estimate of species density and distribution of the main encroacher species in the harvesting area is therefore a prerequisite for the current project, not only for better ecological management but also for better assessment of harvestable stock. In this regard, two developments are relevant to such

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[18] Note: The MAWF / GIZ Bush Control and Biomass Utilisation Project initiated a consultancy titled: "Development of a Bush Information System (BIS) for Mapping and Quantification of Bush Encroachment and Woody Biomass Potential in Namibia'', which may at least partially fill this knowledge gap.

an initiative. First, the land cover data developed and compiled by the European flagship Copernicus programme for monitoring the Earth[19] in the form of woody cover (TC) is a welcome step in the right direction and can be seen as a first-attempt guideline for the spatial planning of harvesting initiatives. These data show that the highest woody cover for the harvesting area occurs in an arch around the harvesting area's northern, eastern and to an extent its southeastern flank, as well as being associated with the Otavi Mountains and the Waterberg Sandstones to the south (Figure 27A).

Second, the LDN Pilot Project of the Ministry of Environment and Tourism has refined a method to determine bush density from remote sensing data, validated through extensive ground-truthing. This project was implemented for the Otjozondjupa Region, but because the approach is very similar to what is required for the harvesting area in the current project, we reproduce some their findings here simply to illustrate the concepts and potential for monitoring and management of the restoration goals (BOX A; Figure 26). A key addition that is required is to estimate changes in cover and to correlate these with edaphic and climatic variables. We illustrate this type of analysis in BOX B below.

Our original thinking was that this is a PhD-level project. In light of the progress made for the LDN Pilot (Hengari 2017) to establish methods, it might be possible to downgrade it to a Masters-level.

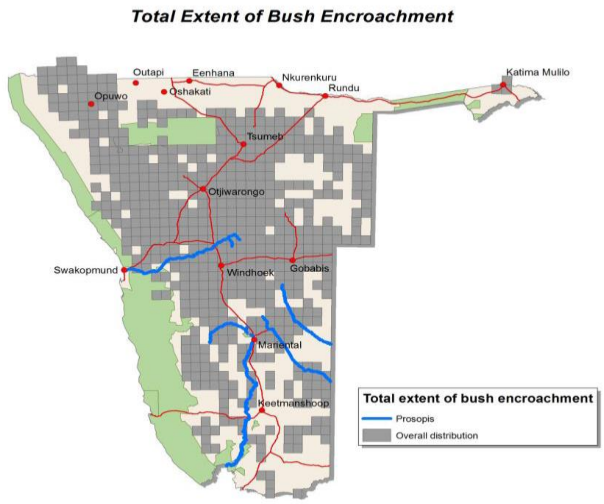


Figure 24. The distribution of encroacher species (grey squares: all species, blue lines: Prosopis) across Namibia according to the SEA study (SAIEA 2016).

SAIEA (2016) notes that "..It is presented as an incremental improvement … but cannot be considered to be very accurate as it is not based on recent hard data from ground and/or aerial surveys"

[19] https://land.copernicus.eu/global/

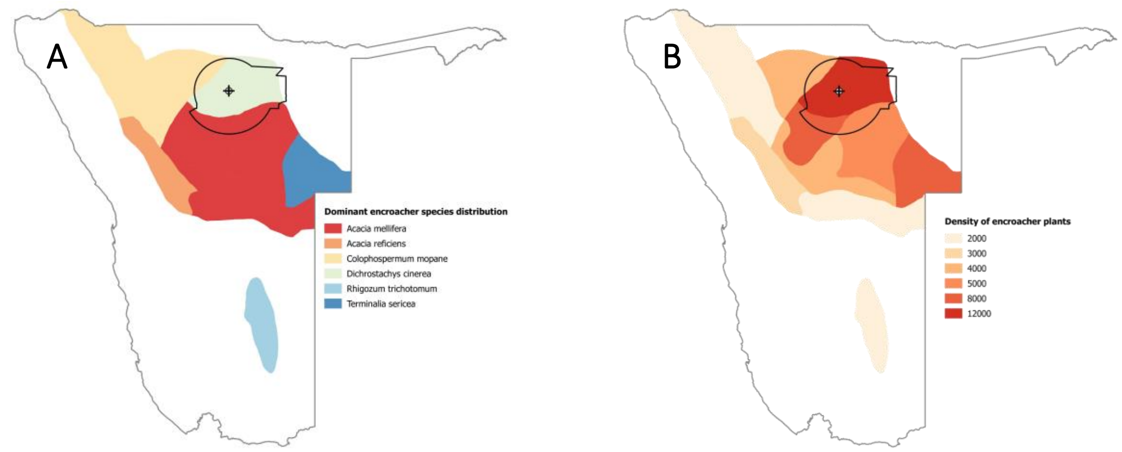


Figure 25. A) The areas where specific encroacher species tend to dominate. B) Rough estimates of encroacher species density. Source: data downloaded from www.the-eis.com, based on Bester (1996; 1998).

BOX A: Illustration of concept 1

Hengari (2017) reports on the results of the Pilot Land Degradation Neutrality Project of the Ministry of Environment and Tourism, as implemented in the Otjozondjupa Region. This study contains many aspects that are directly transferrable to the Biomass Project's management.

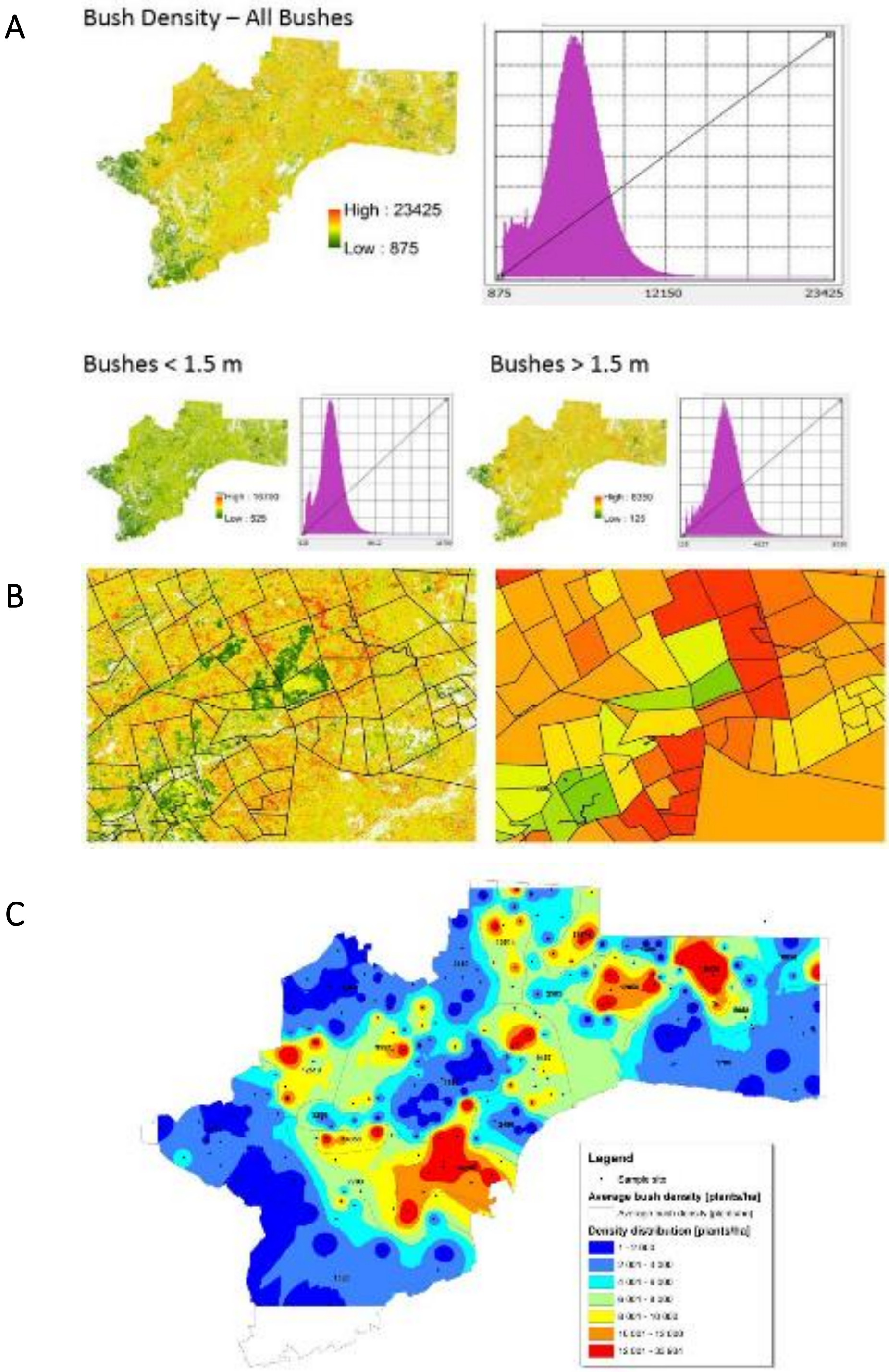


Figure 26. Examples of products from the LDN Pilot Project of the MET (Hengari 2017). A) Bush density (bushes/ha) distributions for all bushes, and those less than and greater than 1.5 meters. Reproduced from Nijbroek (2016). B) Bush density maps of the Otjozondjupa region, as produced for the LDN project of the MET (Hengari 2017; Nijbroek 2016). C) Heatmap of bush density showing more categorical division of areas into affected zones (Reproduced from NNF 2016, based on work done by CIAT and reported in Nijbroek 2016).

See Nijbroek (2016) for detail on methodology used.

BOX B: Illustration of concept 2

Current understanding of savanna dynamics suggests that rainfall, as mean annual precipitation (MAP), is a key driver of percentage woody cover (Sankaran et al. 2008). Our preliminary analysis using data sourced from the European Copernicus project and the WorldClim data set on precipitation (Fick & Hijmans 2017) suggests a more complex relationship between rainfall and woody cover in the study area, with some areas showing a tendency for woody cover to decline with increasing rainfall rather than showing varying rates of increase only (Figure 27B) as might be expected. This could be a result of existing harvesting operations, or local edaphic conditions, or even fire (although Figure 27B rather suggests the opposite relationship with fire [Figure 18] for at least the central mountainous areas). Overall however, some areas do show the expected dependency of woody cover on rainfall, particularly in the Otavi Mountain area. It must be noted however that this correlation analysis is a preliminary attempt at understanding the dynamic aspects of encroachment and requires further development before it can be used as a management tool. The analysis in Figure 27B is therefore presented here simply as an example of how planning as well as monitoring and evaluation can be approached. **More work is required to validate both the woody density and precipitation data sets, and the really important factors to include are long-term variation in rainfall and spatial-temporal occurrence of high-rainfall clusters as well as higher resolution spatial data on soil types and abundance of encroacher species**. These factors will play a large role in determining re-growth potential and hence in management of both harvesting itself and aftercare.

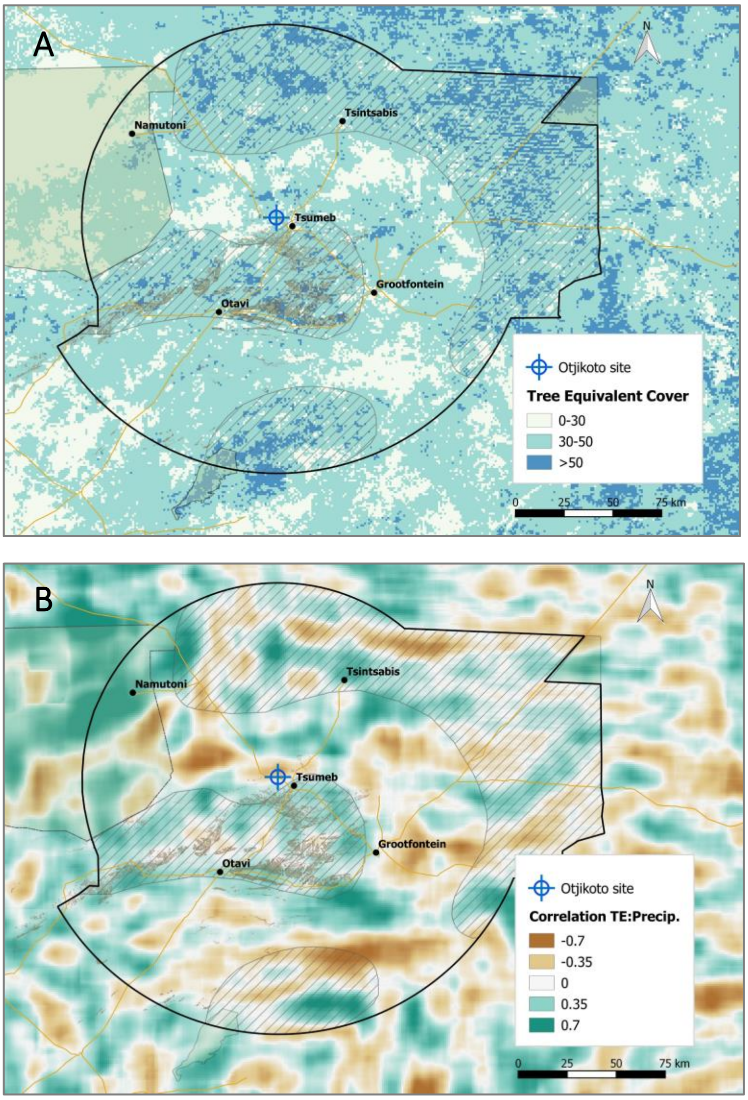


Figure 27. A) Tree cover (TC) over the study area. Cross-hatched areas indicate concentrations of relatively high TC. B) Correlation of TEC in (A) with long-term average annual precipitation (Figure 17). Cross-hatched areas indicate concentrations of relatively high TEC.

The woody cover data were sourced from https://land.copernicus.eu/global/. Precipitation data were sourced from Fick & Hijmans (2017). Correlations were calculated in Excel (after re-sampling all data to a 1km grid) and displayed in QGIS 2.14. The colour of each 1 km^2 pixel represents the relative value of the Pearson's R correlation of all pixels in a 10 x 10 km square surrounding it, between the two raster data sets. Precipitation data are displayed in Figure 4.

2. An understanding of the effects of harvesting on ecological integrity and rangeland productivity

This is a high priority study, we suggest that it should commence with the first operational harvesting to provide suitable study areas for contrasting harvesting and control areas over different time scales (e.g. short term and long-term effects). As part of the current project, we completed an assessment of the effects of harvesting on a range of community structural variables. The results of this study, which we conducted at three different sites where harvesting had taken place at various times in the past (see Figure 2), are summarised in Section 8.1 and Appendix 7. Irish (2018) also investigated the effect of bush clearing on invertebrate communities. However, with their limited spatial and temporal scope these studies should be considered as pilot trials for a proper investigation into the effects of harvesting on vegetation, vertebrate and invertebrate community integrity and the productivity of the grass layer and livestock production. It is also necessary to obtain a better understanding of the way in which soil parameters characteristics, time of harvesting, method of harvesting, after care/maintenance, land use before and after, and others affect the outcome of harvesting. Results from this study are required to assist in determining the best management options for long-term successful outcomes.

A closely related issue concerns the use of arboricides to kill woody species. Although arboricides are considered safe if they are applied according to label instructions (Honsbein et al. 2012 in SAIEA 2016), these tests were done in mesic systems in the northern hemisphere. There are still many unknowns about their use in semi-arid and arid savannas in a Namibian context. Different arboricides differ in active ingredient and chemical properties, mode of application, time to breakdown in the environment and potential to have negative environmental impacts. Farmers have reported unexpected mortalities of large trees, apparently from underground factors concentrating soil-applied arboricides (SAIEA 2016). This occurred despite them reportedly following label application instructions. The long-term residual effects of arboricides have also not been well studied in a Namibian context (SAIEA 2016).

This topic is suggested to be investigated as part of the research programme – issues that need to be resolved are the differential effects of different types of arboricides, the cumulative effects of putting so many kilograms of the compounds into the environment, their long-term effects, the extent of the impact on non-target species (with emphasis on species of conservation concern and protected species) and ways in which this collateral damage can be minimised.

3. Cost-effective monitoring indicators

This is a high priority study because of its practical value. This study could be combined with Study 1 above and can similarly draw from experiences in the LDN Pilot project in Otjozondjupa (Hengari 2017).

Regardless of the data set or analytical method used, there will be a critical need for ground-truthing. It is therefore necessary to 1) identify key ground-based indicators/proxies of savanna structure, function and composition, 2) to determine the most cost-efficient, scientifically robust remote sensing option that will allow long-term monitoring to detect trajectories of change and thus to determine whether the project is reaching its restoration goals, and 3) to validate the remote sensing products.

4. Defining the benchmark: What does the most diverse, resilient and productive savanna look like?

This is a second-level priority project, and some of its objectives could be integrated into Projects 1 and 2, but the demands of a Masters-level project mean that it will probably be too ambitious to expect to integrate its key question into either of the other two and still obtain a quality answer. Ideally it should be a standalone study and that is how we define it here.

A lot has been said about the negative impacts of encroachment on diversity and productivity, but apart from the assumption that there should be a lot fewer woody plants, there has been little attention paid to understanding what it should rather look like. Considering that an important goal of the overall project is the restoration of savanna ecological integrity and grass layer productivity, a description and understanding of the target condition is a prerequisite.

Evidence is mounting that the highest overall biodiversity in savannas occurs at intermediate woody densities. Low diversity often occurs in severely encroached or totally cleared areas, but may include specialized species. Therefore a combination of mostly open, harvested areas but with patches of dense, bush encroached areas will probably strike a balance between gained productivity and functional diversity (Appendix 7). Generally it is also known that the most biologically diverse ecosystems tend to be the most resilient and possibly the most productive. This is not necessarily the case and if productivity and biodiversity targets diverge, we need to understand how to manage harvesting so that neither aspect suffers at the landscape scale.

For this, it is necessary to understand what the relationship is of woody cover and its spatial arrangement to biological diversity and grass layer productivity. Simultaneously, a description is needed of the structure, function and composition of various structural types, emphasising remnant habitats that have undergone the least disturbance.

This is effectively a definition of the restoration target and is directly related to projects 1 and 2. Where project 1 asks “where are the most encroached areas?”, project 2 focuses on the encroached end of the spectrum and asks, “what happens when we decrease the woody density in different ways?”. In contrast, this project focuses on understanding the least encroached part of the gradient.

C. Biodiversity Impact Assessment

9 Introduction

Although the ultimate impact of restoring harvested areas will be positive with appropriate post-harvesting maintenance, negative impacts are bound to take place during the harvesting process and where mitigation measures fail or are not followed. Savanna ecosystems are by definition very complex (SAIEA 2016) and therefore difficult to fully understand and predict responses to disturbances and management interventions.

10 Impacts

Impacts were tabulated, one impact per table. Each table represents an analysis of an impact (or a few related impacts) that may occur to a biodiversity feature or function in response to several potential risk sources. Risk sources are here used as synonymous with impacting activities or agents.

Each table is colour coded at the top to indicate the linear infrastructure life cycle stage in which the specific impact may occur, in the following way:

CYCLE	COLOUR CODE
CONSTRUCTION / HARVESTING	Dark red-brown
OPERATIONAL / POST-HARVEST MANAGEMENT	Dark blue
CLOSURE/DECOMMISSIONING	Green

The impacts were analysed, first in terms of the mechanisms through which it may occur (called "Nature of impact" in the table), and second in terms of the criteria in Table 1. Significance was assigned according to the Hacking Method (see Section 2.3). Mitigating actions as well as monitoring activities are suggested and each table also has a section wherein further management and study recommendations and relevant notes are provided.

IMPACT 1.	**Loss of habitat, destruction of animals and plants at the Project Site**		
PROJECT LIFE CYCLE STAGE: CONSTRUCTION			
SOURCE OF RISK: Clearing of existing natural bush before construction of the Project Site			
Nature of impact	• This is a footprint effect: all animals and plants inside the footprint of infrastructure associated with the Project Site and its operations will be killed, removed or driven away prior to construction		
Status	NEGATIVE		
Level of impact	Habitat, species, populations		
Impact without mitigation			
SEVERITY/NATURE	M	CONSEQUENCE	Medium
DURATION	M	PROBABILITY	Medium
SPATIAL SCALE	L	SIGNIFICANCE	Medium
Management/ Mitigation	• Keep footprint as small as possible within the design brief • Do not clear areas that are not within the infrastructure footprint or outside the fire safety buffer of infrastructure • If necessary, thin out encroacher species in surrounding areas according to harvesting guidelines • As far as possible, do not remove large trees of any species		
Impact with mitigation			
SEVERITY/NATURE	M	CONSEQUENCE	Medium
DURATION	M	PROBABILITY	Low
SPATIAL SCALE	L	SIGNIFICANCE	Low
Monitoring	• Monitor the clearing of vegetation prior to construction to ensure that the guidelines above are adhered to		
Additional recommendations and notes	❖ The habitat on the site chosen for the Project Site is considered to be modified as a result of past disturbance or multiple disturbances. Woody density is high and comprises several encroacher species. As such the loss of plants and animals from the site is not considered to be of any real significance in the context of the distribution and extent of this particular type of habitat in the region		

IMPACT 2.	**Pollution of habitats of plants and animals at the Project Site**		
PROJECT LIFE CYCLE STAGE: CONSTRUCTION		OPERATIONAL	
SOURCE OF RISK: Pollution of environment during operation through generation of tars, ash and harmful effluents by Project Site			
Nature of impact	• Spillage of hydrocarbons, paints and other chemicals • By-products of the Project Site contaminate habitats of plants and animals. This can take the form of ash (216 tons/week for 40MW plant (SLR 2017)), tars from burned biomass (gasification process) or other effluents and reactive gasses produced by the Project Site, including waste water • This is <u>potentially a cumulative impact</u> should pollutants (e.g. air) of other sources combine with that of Project Site		
Status	NEGATIVE		
Level of impact	Habitat, populations		
Impact without mitigation			
SEVERITY/NATURE	M	CONSEQUENCE	Medium
DURATION	M	PROBABILITY	Medium
SPATIAL SCALE	L	SIGNIFICANCE	Medium
Management/ Mitigation	• Design waste product storage, processing areas and power generation methodology to minimize pollution • Proper management plans and clear responsibilities • Frequent inspections by NamPower or outsourced officials • Secondary use found for ash or safe disposal		
Impact with mitigation			
SEVERITY/NATURE	L	CONSEQUENCE	Low
DURATION	M	PROBABILITY	Low
SPATIAL SCALE	L	SIGNIFICANCE	Low

IMPACT 2.	**Pollution of habitats of plants and animals at the Project Site**
Monitoring	• Monitor management adherence to waste product management regulations frequently • Monitor quantities of waste material production such as ash, gas emission concentrations, waste water and other effluent production and quality
Additional recommendations and notes	❖ Promote (subsidize if not profitable) re-purposing of waste materials such as ash (SLR 2017)

IMPACT 3.	**Failure to achieve savanna ecological restoration goals in harvesting area**		
PROJECT LIFE CYCLE STAGE: HARVESTING		PROJECT LIFE CYCLE STAGE: POST-HARVESTING MANAGEMENT	
SOURCE OF RISK: Unclear ownership of management of harvesting component; non-aligned or competing land management objectives of fuel suppliers; perverse financial incentives to clear all woody biomass or to clear indiscriminately; inappropriate harvesting methods; poor post-harvesting follow-up; over-clearing			
Nature of impact	• Although the removal of woody biomass has the potential to greatly improve savanna structure, function and composition, this will only occur if key management principles are followed. These include clear accountability, adherence to basic ecological principles, and adherence to existing guidelines. • Because of the structure of the project, with a single user being supplied by a number of fuel suppliers, responsibilities at the regional scale is not clear and this increases the risk that the project will fail ecologically. • Poor management due to lack of ownership of responsibility for ecological outcomes is almost guaranteed to result in poor outcomes and an increased risk that the restoration goals will not be achieved. • The result can be any of a range of outcomes, from no change in the status quo to specific problems such as proliferation of problematic species and weeds favoured by disturbance, such as gifblaar (*Dichapetalum cymosum*) in Kalahari Woodlands zone, or even, paradoxically, a worsening of bush encroachment if aftercare is not done properly. • Decreased productivity and diversity as a result of poor practice and poor aftercare. • This is a <u>potentially cumulative impact</u>.		
Status	NEGATIVE		
Level of impact	Habitat, species, ecosystem, ecosystem function		
Impact without mitigation			
SEVERITY/NATURE	H	CONSEQUENCE	High
DURATION	H	PROBABILITY	Medium
SPATIAL SCALE	M	SIGNIFICANCE	High

Management/ Mitigation	• Mitigating this potential impact involves the definition and implementation of measures to decrease the risks of failure to achieve savanna restoration. Because of the complexity of the task, we cannot make specific recommendations about the structure or function of the measures, but we do identify the critical characteristics that are required. These could include:
	  o Clear authority and a governance structure have to be established, with some form of central supervision and accountability.
	  o Management based on an Adaptive Management approach (see Notes for more detail), including explicit ecological goals and science standards;		

IMPACT 3.	**Failure to achieve savanna ecological restoration goals in harvesting area**		
	○ Alignment with FSC standards, although actual certification is not required. By aligning and implementing the FSC standards would allow for industry best practices to be complied with. ○ Implementing FSC standards would require displaying long term commitment by fuel suppliers which may be the required model to achieve central supervision and accountability ○ Regular training of fuel suppliers on the ecological principles that underlie savanna dynamics (see Section 7.11 in the Baseline Study section of the current report), the important species and ecological features/functions, specific cutting guidelines and aftercare. • Develop a standard environmental management plan template for fuel suppliers. This should include a requirement to adhere to at least the following commitments: ○ Development of a site-specific harvesting map that should delineate sensitivity zones based on the overarching sensitivity map in Figure 22 in the current report and on the description of the sensitivity zones (also in the current report) and on the list of important or protected species in Appendix 1 and 2 (also in the current report). ○ Adherence to the harvesting guidelines as described in the National Harvesting Guidelines (Pallett & Tarr 2017; Appendix 8), the best-practice principles defined in Section 17 below and FSC standards as interpreted per Management Unit (FSC's Forestry Management Unit). ○ Promote spatial heterogeneity in harvesting intensity, e.g. for every 10ha harvested (according to TE-rainfall guidelines) at least one 30-50m diameter area is left untouched (encroached). ○ Monitor compliance to the site-specific EMPs.		
Impact with mitigation			
SEVERITY/NATURE	H+	CONSEQUENCE	High
DURATION	H	PROBABILITY	Medium
SPATIAL SCALE	M	SIGNIFICANCE	High Positive
Monitoring	• Monitor site-level and regional changes in savanna structure relevant to agreed ecological goals. • Keep detailed records of biomass and species harvested. • Monitor adherence of fuel suppliers to their EMPs.		
Additional recommendations and notes	❖ Adaptive Management Structure: Adaptive Management entails a continuous assessment of the condition of savanna structure against ecological goals and a decision-making process where management actions are changed ("adapted") to reflect the current and expected future conditions in such a way as to maintain progress towards goals. Implicit in this structure is the definition of measurable ecological goals and a monitoring programme.		

<table>
<tr><th>IMPACT 3.</th><th>Failure to achieve savanna ecological restoration goals in harvesting area</th></tr>
<tr><td></td><td>❖ Monitoring Programme: A monitoring programme can take many forms, but the most important aspect is that it should provide information that will allow rational and relevant assessment of progress. The most robust design is an asymmetrical BACI (Before-After-Control-Impact) experimental structure (see Underwood 1994). The choice of indicators will be critical. The most defensible approach would be field-based estimates of species abundance and distribution but fieldwork is generally assumed to be too costly to allow much more than a few short-term and local attempts. There is thus a strong bias to go for remote sensing. However, remote sensing data has little meaning without proper field-validation. We therefore propose a phased approach: an early study initiated during the construction phase to determine the extent of bush encroachment in the harvesting area while simultaneously determining the most appropriate indicators and ground-truthing these with the aim of developing a cost-effective approach based mostly on remotely-sensed data.
❖ Savanna ecosystems are by definition very complex (SAIEA 2016) and therefore difficult to fully understand and predict responses to disturbances and management interventions. As such, the risks of this impact are high, even with proper management. Risks can however be decreased to a manageable level by increasing knowledge (i.e. filling key knowledge gaps – see Section 0 of the Baseline study) and adhering to the standards, guidelines and rules (see Guidelines [Appendix 8] and Sections 13 and 15 in the current report). If risks are managed in this way, the outcomes will be, on balance, positive for biodiversity regardless. See also Box 1 below for more detail.</td></tr>
</table>

Box 1: About the risks of not achieving ecological restoration and productivity goals

One of the perceived benefits of the Encroacher Bush Biomass Power Project is the restoration of rangelands in harvested areas (SLR 2017). To realise this objective, proper after-care and management of harvested areas are crucial for successful restoration (SLR 2017). There is, however, a real risk that the restoration goals will not be met because post-harvest control of re-sprouting and newly established woody plants is inadequate. Many examples exist where initial woody clearing or harvesting without aftercare reverted to a bush encroached state, which might be worse than the initial encroached state (Smit et al. 2015).

With harvesting of woody biomass there is a high risk that desirable (non-encroacher) species are indiscriminately removed (SAIEA 2016). The cumulative impact of widespread cutting of valuable and protected trees could be significant (SAIEA 2016). Experiences in the related charcoal industry clearly showed that felling wrong trees is a real issue with widespread impact. Non-protected species identified to be at risk in the harvesting area include *Olea europaea*, *Combretum collinum*, *Combretum psidioides*, *Securidaca longepedunculata*, *Philenoptera nelsii* and *Kirkia acuminata*. Cumulative losses due to a proliferation of woody harvesting over much of the range of these species should be frequently assessed in future.

Reasonably long-term loss of fruit resource for fauna and humans due to destruction of above-ground growth of non-protected fruit-bearing shrubs and trees, such as *Grewia* spp. and *Ximenia* spp., in all zones and suffrutex fruit bearing species such as *Diospyros chamaethamnus* and *Salacia luebbertii* in the Kalahari Woodland zone. The impact of this will depend on the extent of harvesting within a given area over a given time. If large parts of a single area are harvested in a short space of time it will be a higher impact than otherwise.

Improvement of rangeland productivity: A second perceived benefit of harvesting encroacher bush is the increased productivity of the herbaceous layer and concomitant increase in grazing capacity (Smit 2004). This is entirely possible. In our field experiment, herbaceous biomass increased with 80% in harvested areas compared to encroached control areas nearby. However, there is little data on the mix of fodder grasses that return after harvesting, how stable these are in the long-term and what specific combination of harvesting treatments will ultimately be the best.

Recovery of savanna heterogeneity and biodiversity: Ecological heterogeneity underpins biodiversity. Ecological heterogeneity describes the types of resources and environmental constraints, their respective spatial configuration and links ecological structure and function (Du Toit et al. 2003). Bush harvesting has the potential to increase ecological heterogeneity by creating patchiness in the landscape at different spatial scales and vertical strata: harvested patches, several hundred hectares each, in bush encroached landscapes; bush thickets for example 30m in diameter are left in harvesting areas and variation in height strata such as open grassy patches between trees and different combinations of shrub and tree layers.

In savannas, evidence is mounting that the highest overall biodiversity occurs at intermediate woody densities. Low diversity often occurs in severely encroached or totally cleared areas. Nevertheless, little local knowledge is available to define what “intermediate” woody densities are in the harvesting area.

IMPACT 4. Large scale loss of protected woody species, including fruit-bearing species important for humans and other fauna, as well as rare, iconic and timber species due to indiscriminate and excessive take-off			
PROJECT LIFE CYCLE STAGE: HARVESTING			
SOURCE OF RISK: Accountability of management of harvesting component unclear or poorly enforced; non-aligned or competing land management objectives of fuel suppliers; unselective harvesting methods and equipment			
Nature of impact	• Loss of individuals and populations of woody plant species that are formally protected in Namibia, or are endemic and thus experience greater risks, or are sparsely distributed throughout their range, or are simply iconic members of intact and healthy savannas. See Notes for detail. • Loss of individuals and populations of protected or endemic succulent, shrub and herbaceous plant species because of damage by the mechanical harvesting process. • This is a cumulative impact: due to the proliferation of bush to energy projects, such as Ohorongo and others, we must look at cumulative losses over much of the range of some species in Namibia, particularly broadleaved trees.		
Status	NEGATIVE		
Level of impact	Ecosystem, populations, species		
Impact without mitigation			
SEVERITY/NATURE	H	CONSEQUENCE	High
DURATION	H	PROBABILITY	Medium
SPATIAL SCALE	L	SIGNIFICANCE	High
Management/ Mitigation	• Avoid harvesting of the No-go areas by not accepting wood that have not been proven to be harvested appropriately. See the map in Figure 22 for a regional-scale indication of the location of sensitivity zones: this is a first-level filter to indicate the relative sensitivity of a specific harvesting unit/farm. For each management unit, a detailed, site-specific map should be drafted by the fuel supplier, focusing firstly on the presence and spatial organisation of important ecological processes (e.g. drainage lines) and habitat features (e.g. large old trees for nesting) and secondly on the location and density of important tree species (see Appendix 1 and 2) • These site-level sensitivity zones should indicate where harvesting should be either avoided (i.e. No-go zones) or carefully applied following cutting rules as defined in Appendix 8 and in Section 0 below. Ensure adherence to rules in this regard. • Only use harvesting methods and/or machinery that are able to selectively harvest encroacher bush while avoiding damage to desirable species. • Regular training events where all harvesting contractors, land owners, bush cutters and machine operators are instructed about which woody plants to target, which ones to avoid and how to calculate TEs/ha. Training should include enough ecological principles to provide context for these rules and guidelines. For example: the importance of diversity of structure and composition for resilience and productivity. • Supervision to prevent cutting of non-target plants.		

IMPACT 4. Large scale loss of protected woody species, including fruit-bearing species important for humans and other fauna, as well as rare, iconic and timber species due to indiscriminate and excessive take-off

	• Frequent inspections of harvested biomass and harvesting operations by Forestry officials and/or appointed Environmental officials (preferably) • Fuel suppliers should be held accountable to follow biomass harvesting guidelines (see Appendix 8 and Section 0 below).		
Impact with mitigation			
SEVERITY/NATURE	L	CONSEQUENCE	Medium
DURATION	H	PROBABILITY	Medium
SPATIAL SCALE	L	SIGNIFICANCE	Medium
Monitoring	• Before- and after harvest inventories of the population densities of species of valuable species • Long-term monitoring of population trends/health of valuable species to also include the post-harvest management efficiency		
Additional recommendations and notes	❖ **At risk species**: Several plant species across all growth forms fall in the category of rare, threatened, endangered, protected or iconic plant species. These are summarised in Appendix 1 and 2. o The first aspect is the formally protected species, for which a risk assessment has led to legal protection which dictates steps that have to be taken to prevent negative impacts. These steps are set out in the relevant Acts and Regulations. o There are however many others that are known to be rare or threatened for various reasons (e.g., existing over-harvesting in other parts of their range), that should be managed to prevent loss of individuals. o Some other species are only encountered in intact, climax savannas and are thus indicators of a healthy ecosystem. Such an area will not be encroached and should therefore not be harvested. ❖ Whatever other steps have been identified, in terms of the current project the management of all of these at risk species, and **all mitigation options, depend on the drafting of a site-level sensitivity map** that should include No-go zones that delineate their presence (in addition to delineating functionally important features such as drainage lines). The mechanism through which the drafting of a map and a check of its veracity is implemented is not within our scope. We do however point out that this type of supervision should happen at the regional (i.e. harvesting area) level. ❖ Measurement and evaluation of the effects of harvesting on protected species should form an explicit **part of the monitoring programme**. ❖ See Box 3 for more detail on this issue.		

Box 3: About managing impacts on protected species

One of the important environmental goals of the Biomass Power project is to use the biomass harvesting process as a springboard to convert bush encroached land in productive and diverse rangelands (SLR 2017). The enormous potential woody resource compared to the supply requirements for a biomass power plant means that re-harvesting (bush farming) is not required in the foreseeable future. In any bush harvesting operation there is a high risk of felling protected or desirable plants such as palatable and evergreen trees and shrubs (SAIEA 2016). Large trees, even dead ones, have important key stone functions in savannas as nesting and perching sites for several birds of conservation importance, as well as important ecological services related to nutrient cycling and providing habitat niches for specific organisms. Evergreen shrubs and trees offer browse during the late dry seasons for browsers such as kudu, eland, giraffe and goats.

Mitigation measures such as training in tree identification by operators, close supervision during the harvesting process and frequent inspections may lessen this impact, but this might be more successful in certain areas than others, hence risk affecting biodiversity properties negatively. Areas with a high occurrence of protected plants evenly distributed among encroacher species has a higher probability of losing protected plants than harvesting operations in monocultures of the target encroacher species. Also, very dense thickets will impede visibility, resulting in recognition rates of desirable species. Our observations, corroborated by the Tree Atlas distribution data of protected tree species, suggest that such unwanted mixtures are often encountered in the harvesting area. Well trained manual Fuel suppliers or selective, slow moving mechanical harvesting approaches will be best suited for such mixtures.

Surviving desirable and protected species may also be unintentionally killed or damaged during after care control in mixtures, especially where soil applied aboricides are used.

IMPACT 5.	**Loss of and disturbance of animals in harvesting area**		
PROJECT LIFE CYCLE STAGE: HARVESTING			
SOURCE OF EFFECT: Direct killing and maiming of animals due to accidents during harvesting process and transport of biomass on site when using heavy machinery and when transporting biomass to the Project Site; disturbance of animals during operations via human presence, noises, smells and movement of machinery; increased poaching and illegal capture of animals by fuel supply staff			
Nature of impact	• In bush-harvesting operations, labourers operate and camp on the farms where harvesting is taking place. The presence of people, vehicles and the operating machinery potentially may disturb animals, notably nesting vultures and raptors, but also other animals including amphibians, reptiles and mammals (SAIEA 2016). • Poaching is also likely to increase with the additional people that work and live close to animals, birds and plants of value (bush meat or illegal trade market). These include common game species such as small antelope species, warthog, kudu, oryx and eland, but also species of conservation concern such as pangolins, tortoises and leguaans and several birds (SAIEA 2016, Scott & Scott 2018). In addition, the harvesting area is adjacent to three national parks. The proximity of the Etosha and Waterberg National Parks carries the additional risk of fuel supply staff assisting rhino and elephant poaching rings by supplying local information and offering ways for poachers and goods to be transported. • Decreased population sizes • Disruption of animal activities, notably that related to breeding • Road accidents • Poaching and illegal trade of species		
Status	Negative		
Level of impact	Ecosystem, species, populations		
Impact without mitigation			
SEVERITY/NATURE	M	CONSEQUENCE	Medium
DURATION	L	PROBABILITY	Medium
SPATIAL SCALE	M	SIGNIFICANCE	Medium
Management/ Mitigation	• Do not accept wood that originated from the No-go areas or from the buffer zone along the National Parks (should this be enforced by MET). See the map in Figure 22 for a regional-scale indication of the location of sensitivity zones: this is a first-level filter to indicate the relative sensitivity of a specific harvesting unit/farm. For the harvesting unit itself, a detailed, site-specific map should be drafted focusing firstly on the presence and spatial organisation of important ecological processes (e.g. drainage lines) and habitat features (e.g. large old trees for nesting) and secondly on the location and density of important plant species (see Appendix 1 and 2)		

IMPACT 5.	**Loss of and disturbance of animals in harvesting area**		
	• These site-level sensitivity zones should indicate where harvesting should be either avoided (i.e. No-go zones) or carefully applied following cutting rules as defined in Appendix 8 and in Section 0 below. Ensure adherence to rules in this regard. • Give preference to harvesting methods that allow smaller animals to move away (i.e. slow moving machinery or manual methods) • Fuel suppliers should be encouraged to assign clear responsibilities and control over field personnel at all time • Fuel suppliers should be encouraged to educate field personnel to respect wildlife • Regulations and strict adherence to speed and traffic rules • Ensure swift law enforcement in poaching cases by reporting immediately to the police and to community anti-poaching organisations • Restrict driving at night • Enforcing a buffer zone around Etosha and Waterberg National Parks		
Impact with mitigation			
SEVERITY/NATURE	L	CONSEQUENCE	Low
DURATION	L	PROBABILITY	Low
SPATIAL SCALE	M	SIGNIFICANCE	Low
Monitoring	• Recording of poaching incidents and educational efforts • Animal road accident statistics • Vehicle movement and traffic rule adherence (e.g. GPS tracking system)		
Additional recommendations and notes	❖ None		

<table>
<tr><td colspan="4">IMPACT 6. Disturbance of soil, loss of soil fertility and arboricide after-effects</td></tr>
<tr><td colspan="4">PROJECT LIFE CYCLE STAGE: HARVESTING</td></tr>
<tr><td colspan="4">SOURCE OF EFFECT: Operation of heavy machinery and vehicles in felling woody plants, processing and transporting woody biomass; removal of nutrients from the harvested area contained in biomass; killing or retarding non-target plants with arboricides use</td></tr>
<tr><td>Nature of effect</td><td colspan="3">Harvesting with heavy machinery to fell, chip, and transport woody material, which will compact, disturb, and expose the soil surface (De Wet 2015);
Compaction of soil, disturbance of soil layer;
Erosion and degradation through loss of topsoil;
Loss of nutrients from the ecosystem;
Concentration of arboricides killing non-target plants and contaminating drainage systems or ground water
Potentially affects the physical destruction of plants and animals above the soil surface, as well as soil macro-fauna (burrowing invertebrates, amphibians, reptiles and mammals) and microorganisms below the soil surface
<u>This is a potentially cumulative impact</u></td></tr>
<tr><td>Status</td><td colspan="3">NEGATIVE</td></tr>
<tr><td>Level of impact</td><td colspan="3">Ecosystem, habitat</td></tr>
<tr><td colspan="4">Impact without mitigation</td></tr>
<tr><td>SEVERITY/NATURE</td><td>M</td><td>CONSEQUENCE</td><td>Medium</td></tr>
<tr><td>DURATION</td><td>M</td><td>PROBABILITY</td><td>Medium</td></tr>
<tr><td>SPATIAL SCALE</td><td>M</td><td>SIGNIFICANCE</td><td>Medium</td></tr>
<tr><td>Management/
Mitigation</td><td colspan="3">Fuel suppliers should be encouraged to avoid very sensitive zones and no-go areas (see Impacts 4 and 5 for more directives in this regard)
Fuel suppliers should be encouraged to follow biomass harvesting guidelines (see Appendix 8 and Section 817 below). It is important not to over-clear: Tree Equivalents/ha that should remain after thinning should follow the recommended rainfall-TE guidelines per dominant encroacher species.
Fuel suppliers should be encouraged to use appropriate harvesting machinery and experienced drivers
Land users should be encouraged to provide grazing animals with mineral lick supplements when grazing harvested areas to counter the nutrient loss from biomass removal
Fuel suppliers should be encouraged to use manual aftercare (e.g. small-scale operations). When using chemical control stem/foliar applied arboricides instead of soil-applied arboricides should be promoted. Ensure that the chemicals used and the waste management of chemicals comply with FSC pesticide standards.</td></tr>
</table>

IMPACT 6.	**Disturbance of soil, loss of soil fertility and arboricide after-effects**		
	• When using manual aftercare, plants should be uprooted to prevent regrowth. Manual aftercare is not recommended for controlling *Dichostachys cinerea*, which readily coppices from damaged roots. • Give preference to harvesting methods and machinery that minimally disturb soils, e.g. no blades disturbing soil and no shunting of harvested material over the soil surface. Aftercare using heavy machinery should be discouraged. • When arboricides are used for aftercare, landowners should be encouraged to use an integrated post-harvesting approach by including fire and browsers to lessen arboricide use.		
Impact with mitigation			
SEVERITY/NATURE	L	CONSEQUENCE	Low
DURATION	L	PROBABILITY	Medium
SPATIAL SCALE	L	SIGNIFICANCE	Medium
Monitoring	• Keep records of arboricides amount used and how applied. • Keep records of events such as fire occurrence, browsing levels and intensity, etc.		
Additional recommendations and notes	• The rating of this impact as Medium after mitigation is weighted by the uncertainty of the long-term effects of arboricides, and the potential for it to cause mortalities of protected and other non-target species. Although all compounds have been cleared for use as safe, these tests were all done in mesic systems in the northern hemisphere. There are still many unknowns about their use in semi-arid and arid savannas. This topic should be investigated as part of the research programme – issues that need to be resolved are the differential effects of different types of arboricides, the cumulative effects of putting so many kilograms of the compounds into the environment, their long-term effects, the extent of the impact on non-target species (with emphasis on species of conservation concern and protected species) and ways in which this collateral damage can be minimised. See also Box 4 for more information on this. Should these issues be adequately resolved, it could be possible to downgrade the impact to Low. • Use of fire for rangeland management purposes is regulated and approval must be obtained from the relevant authorities. • See Information Box 4 below for more detail on the nature of the impact on soil nutrients.		

Box 4: Disturbance of soil, loss of soil fertility and arboricides after-effects

Harvested wood biomass also contains nutrients that will be exported from the harvesting area to the Project Site for electricity generation. Estimates of the quantities of various nutrients removed through harvesting were obtained from Rothauge's (2017) biomass quantification study for COWI and subsequent chemical analysis of wood samples from the harvesting area (permission granted by COWI). Table 11 provides a summary of the mean, maximum and minimum exports of specific elements for the extractable wood harvests as determined by Rothauge (2017) for representative sites in the harvesting area. Significant amounts of sulphur, nitrogen, calcium and potassium are removed (Table 11), which may have consequences for the ecology of the harvested areas. From an ecological perspective, many of these losses will only manifest over longer time frames (decades), because much of the elements bound up in wood has a slow turn-over rate in dry ecosystems (fire may release non-volatile elements such as calcium, potassium, magnesium and phosphor rapidly to the soil). How this will affect the harvesting area is not clear at this stage, as few studies have considered this for natural savanna systems. A study on the impacts of clearing and removing *Brachystegia–Julbernardia* (miombo) woodland over a 10-year period in central Zambia showed that grass biomass increased by 20–50% but impacts on topsoil organic matter and available phosphorus were not statistically significant (Chidumayo & Kwibisa 2003). Zimmerman et al. (2017), however, found in a bio-assay at the CCF (Otjiwarongo area) that seedling emergence and height of bio-assay plants after five weeks were greatest in soil collected from uncleared (encroached) sites and lowest in soil from totally cleared areas. They found no evidence of soil fertility restoration in soils collected from an area harvested 13 years previously. On the other hand, bush encroachment often increases soil C and N levels (topsoil) compared to non-encroached sites, except in severe encroachment cases where herbaceous plants are totally outcompeted by woody plants (Hudak et al. 2003). Ideally nutrient losses and soil fertility declines should be compared to pre-encroachment controls, which are rarely available.

Measures to mitigate against the loss of soil fertility include the retention of foliage and small twigs and branches of harvested plants, providing mineral licks to livestock and game in these areas and minimum disturbance of wildlife that use the area (potential source of nutrient imports through dung and urine).

Table 11, Summary of potential chemical exports from wood harvesting. The potential extractable wood is based on four quantitative surveys made in the harvesting area by Rothauge (2017).

Element/Component	Unit	Mean	Minimum	Maximum
Extractable wood	ton/ha	116	44	245
Ash	kg removed/ha	4.6	1.6	9.6
Ash	% of wood	3.9	3.7	4.1
Sulphur	kg removed/ha	66.0	19.2	152.1
Chlorine	kg removed/ha	44.3	14.4	107.9
Nitrogen	kg removed/ha	726.7	218.3	1717.3
Aluminium	kg removed/ha	0.5	0.1	0.8
Calcium	kg removed/ha	99.1	32.8	210.5
Iron	kg removed/ha	0.3	0.1	0.5
Potassium	kg removed/ha	13.6	3.9	31.6
Magnesium	kg removed/ha	4.4	1.3	10.5
Sodium	kg removed/ha	0.2	0.1	0.3
Phosphorous	kg removed/ha	1.2	0.4	2.6

Different chemical herbicides to kill woody plants, arboricides, are available in Namibia. Arboricides are considered safe if they are applied according to label instructions (Honsbein et al. 2012 in SAIEA 2016). Nevertheless, different arboricides differ in active ingredient and chemical properties, mode of application, rates applied, time to breakdown in the environment and potential to have negative environmental impacts. For example, despite following instructions, farmers reported cases where large trees died unexpectedly, apparently from underground factors concentrating soil-applied arboricides (SAIEA 2016). The long-term residual effects of arboricides have also not been well studied in a Namibian context (SAIEA 2016). In terms of the mode of application, arboricides applied selectively to the stems or foliage of target plants is considered the safest from an environmental perspective (Smit et al. 2015). Soil applied arboricides (pellets or liquid) are considered less safe because it requires a higher load of active ingredient to the environment and remain active for several years in the environment.

IMPACT 7.	**Improvement of rangeland productivity**		
PROJECT LIFE CYCLE STAGE: POST-HARVESTING			
SOURCE OF EFFECT: Post-harvest release from woody competition			
Nature of effect	• Increased forage resources for grazing animals; habitat creation for grassland invertebrate and vertebrate species		
Status	POSITIVE		
Level of impact	Ecosystem, habitat		
Impact without mitigation			
SEVERITY/NATURE	M+	CONSEQUENCE	Medium
DURATION	L	PROBABILITY	Medium
SPATIAL SCALE	M	SIGNIFICANCE	Medium Positive
Management/ Mitigation	• Annual post-harvest control of coppicing and establishing woody plants • Sound rangeland management principles applied such as appropriate stocking rates for forage availability, resting for at least significant part of growing season • If desirable perennial grass species are lost or at very low density – reseeding with indigenous, desirable grass species		
Impact with mitigation			
SEVERITY/NATURE	M+	CONSEQUENCE	High
DURATION	H	PROBABILITY	Medium
SPATIAL SCALE	M	SIGNIFICANCE	High Positive
Monitoring	• Determine coppicing and emerging woody plant densities in fixed transects and repeat photographs • Estimate forage standing crop and rangeland condition at end of rainy season according to Local Level Monitoring system • Keep records of grazing/resting periods and stocking densities of livestock and game		
Additional recommendations and notes	❖ Comparatively little is known about the degree to which rangeland primary productivity recovers after harvesting, how sustainable it is with or without maintenance and after care and what the key management actions are that could improve productivity. Additionally, little is known about the ultimate effect of harvesting on livestock production, whether the inputs into harvesting are offset by improved incomes from livestock, and what the key management actions are that could improve productivity. We therefore propose that this should be investigated in a dedicated postgraduate-level study as part of the commitments of the EMP for this project.		

11 Cumulative impacts

Several impacts may have negative cumulative impacts. These include (1) air pollutants from other sources that combine with that of the Project Site to exceed safe thresholds, thereby affecting habitat quality at the Project Site and surrounding area, (2) the failure to achieve restoration goals, which will negatively affect biodiversity beyond the harvesting footprint areas, especially if combined with other failed bush harvesting/control efforts in the study area, and may negatively affect ecological processes that operate at the larger scale (e.g. metapopulation dynamics), (3) large scale loss of cohorts of protected, rare, iconic and timber species which could lead to reproduction bottlenecks, especially if combined with other woody harvesting/control efforts depleting these species in the study area, (4) disturbance of soil which leads to increased soil erosion also affecting downstream and downwind areas, and (5) arboricide residual effects that potentially affect non-target plants and areas, as well as underground water resources.

A positive cumulative effect with a potentially positive outcome could occur as a result of successful restoration that leads to an increase in the productivity of rangelands in harvested areas and on plant and animal diversity and population sizes beyond the harvest areas. This could occur as a result of improved connectivity of open savanna populations (plants and animals) and increased resilience to disturbances (e.g. buffering of drought effects for herbivores due to increased and less variable forage production in restored area).

Significant amounts of wood are currently being harvested by the charcoal and firewood industries in the study area (ref: Social study), therefore cumulative impacts (positive or negative) are likely to occur once the Biomass project becomes operational. Various factors may determine a positive cumulative outcome: Many charcoal producers are currently seeking FSC accreditation, therefore increasing the chance that these harvested areas are responsibly managed. This has the potential to result in a positive cumulative impact if this trend continues and provided that the Biomass project itself has a positive impact. Also, a greater awareness of the need for aftercare and the increasing availability of information about post-harvesting best practices are likely to result in fewer failed projects in future.

12 Impacts summary

- Seven impacts were identified (Table 12), two at the plant site itself and five in the harvesting area.
- Both plant-site impacts are rated as Medium before and Low after mitigation.
- Significantly, of the five impacts expected in the harvesting area, four are potentially cumulative, meaning that their effects should be viewed together with expected similar impacts by other harvesting/bush control operations and that the scope of the cumulative impacts may be more than the sum of the whole. This increases their significance.
- Three of the impacts are of Medium significance (one of which is Medium positive) before mitigation. Of these, one will become Low after mitigation, one will remain Medium and one could potentially become High positive.

- Two impacts are expected to be of High significance without mitigation, and one of these – the loss of special trees because of indiscriminate cutting – could become Medium if all mitigations are adequately applied.
- The final impact is expected to be of High significance without mitigation. This impact is a statement of the risk that the project will not reach its restoration goals, which we expect to be very high without tight management and inbuilt accountability. However, if the recommendations made in this report are followed, the knowledge gaps are filled and the adaptive management framework is effectively implemented, the Encroacher Bush Biomass Power Project has a good chance of leaving a significantly High positive legacy.

Table 12. Summary of impact significance in all three project life stages

STAGE	IMPACT (Impact headings in **bold red** type indicate potential cumulative impacts.)	Impact WITHOUT mitigation	Impact WITH mitigation
	Plant site		
	IMPACT 1. Loss of habitat, destruction of animals and plants at Project Site	Medium	Low
	IMPACT 2. Pollution of habitats of plants and animals at Project Site	Medium	Low
	Harvesting area		
	IMPACT 3. Failure to achieve savanna ecological restoration goals	High (negative)	High (positive)
	IMPACT 4. Large scale loss of protected woody species, including fruit-bearing species important for humans and other fauna, as well as rare, iconic and timber species due to indiscriminate and excessive take-off	High	Medium
	IMPACT 5. Loss of and disturbance of animals	Medium	Low
	IMPACT 6. Disturbance of soil, loss of soil fertility and arboricide after-effects	Medium	Medium
	IMPACT 7. Improvement of rangeland productivity	Medium (positive)	High (positive)

13 Management of harvesting to achieve both rangeland productivity and ecological restoration goals

13.1 Adaptive Management as the most appropriate governance framework

The large-scale extraction of woody biomass from Namibian savannas is a recent development and consequently information on its effect on biodiversity and ecological processes is scant. As can be deduced from the baseline description above, the removal of woody biomass will not automatically achieve ecological restoration goals because it matters critically how the harvesting and aftercare are done. As such, bush harvesting differs from most other development projects in the sense that it has two implicit but potentially opposing objectives: it wants to achieve an ecological restoration outcome through the utilisation of the very system it tries to protect, and it must be economically successful. It is not impossible to achieve both these goals, but it requires commitment from all participants and a particular focus on the governance structure. Below, we summarise best practice implementation of harvesting projects. However, while clearly being necessary, a set of guidelines based on broad ecological principles and experience will not, in the present case, be enough. **Given that an important goal of this project is aiming to achieve restoration outcomes across a large region while harvesting will be in the hands of many participants with diverging agendas, it is essential and critical to create an appropriate governance framework. In this regard it is particularly important to define responsibilities and accountability for overall project objectives**.

For these reasons, and as a first step, we recommend an **adaptive management approach**. Adaptive management entails that management decisions are based upon the best available knowledge at the time, but with effort to improve on this through dedicated research and analysis of monitoring data.

An adaptive management framework has four components:

1. A description of the system and its dynamics,
2. Definition of specific, measurable, achievable, relevant and time bound (SMART) objectives,
3. Definition of ecological management actions, and
4. Definition of a robust monitoring programme to serve as the basis of management decisions and to improve the knowledge base.

We described the system, including specific knowledge gaps, in the Baseline Study of this report. A consultative process with the project proponent, funders and other relevant stakeholders and specialists is recommended to define the SMART objectives, including explicit desired ecological outcomes to aim for. The specifics of management actions and a monitoring programme (the indicators to use, the implementation framework and the handling of data and management decision-making) are in turn dependent on the definition of goals. **As such, the latter three aspects are outside the scope of the current report but are a critical requirement for successful achievement of environmental obligations**. For the definition of the final environmental management plan, we therefore recommend that a consultative process should be undertaken, with a key goal being to define the project-level ecological goals and the governance structure with specific obligations and accountability.

13.2 Role of Environmental Manager

It is recommended that NamPower appoint or task an Environmental Official for the project with enough authority to make binding decisions. To ensure compliance and that high standards are maintained, the compliance auditing shall be conducted by a suitably qualified person with a strong ecological background and preferably with FSC experience. Third party verification is also recommended.

13.3 Decision-making tools

1. The results of the Baseline Study (Section B, Baseline Study of this report), Impact Assessment (Section C, Impact Assessment part of this report) and Research Projects (Chapter 16) as background.
2. The resource map drafted as an outcome of Research project 1 and the results of Project 2 (see Chapter 16 below for a description of the recommended research) will define the basic trajectory along which the ecological changes should occur.
3. The results of Project 2 will furthermore inform decisions about harvesting strategy and guidance provided to landowners.
4. A Monitoring Programme which provides data for decision making.

14 Carrot, stick and education: equally important keys to success

Prescriptions for bush harvesting activities, harvesting equipment, responsible parties and the exact locations of harvesting areas are not yet decided (SLR 2017). Nevertheless, it is understood that harvesting will be done by third party fuel suppliers on land where the required Environmental Clearance Certificate has been granted (SLR 2017). Assuming this to be the case, and given the overall objective of restoration, the way fuel suppliers are either regulated or incentivised to ensure a positive ecological outcome will clearly be one of the key issues to solve.

14.1 Incentivising through certification

One potential solution is to create an incentive scheme, similar to the Forest Stewardship Council Certification process. This can be achieved by aligning the project to the FSC standards, although actual certification is not required. By aligning and implementing the FSC standards would allow for industry best practices to be complied with. Implementing FSC standards would require displaying long term commitment by fuel suppliers which may be the required model to achieve central supervision and accountability.

14.2 Harvesting permits, Environmental Clearance and site-specific Environmental Management Plans

The current Forestry regulations stipulate that all woody harvesting activities in areas greater than 150 ha per annum requires a forestry harvesting permit and an Environmental Clearance Certificate (ECC) as required by the Environmental Management Act (SAIEA 2016), but that areas of less than 150 ha per annum only need a forestry harvesting permit (Pallett & Tarr 2017). For larger projects, such as the Encroacher Bush Biomass Power Project, which intends to harvest more than 5000 ha per annum, a full EIA with Environmental Management Plan is required (SAIEA 2016). Should the current project successfully obtain environmental clearance, it would be for all harvesting operations related to it. For improved control over local harvesting processes and especially post-harvesting management accountability, we recommend that *all* harvesting areas regardless of size obtain a Forestry harvesting permit (SAIEA 2016). However, in line with the Bush Harvesting guidelines (Pallett & Tarr 2017) we recommend that every management unit (such as a farm for instance) should have its own site-specific Environmental Management Plan (EMP), customized according to the unique environmental circumstances of the area. For the current project that can only provide a sensitivity map at the regional scale, it implies that the individual EMP should include a sensitivity map using the same categories that we employ in this report: three increasingly sensitive usage categories and one No-go. This is a form of permitting but is contractual in nature rather than being regulatory.

It is recommended that fuel suppliers are contractually obligated to follow the general and site specific Environmental Management Plans, which should preferably be monitored and evaluated by NamPower staff in collaboration with Directorate of Forestry officials. An alternative would be to appoint an independent monitoring and evaluation entity to support or replace NamPower staff.

14.3 Aftercare responsibilities

It is recommended that the post-harvest (after) care to achieve rangeland restoration should be the responsibility of the fuel supplier, who signs an agreement with regards to long term commitment, compliance and the supply of biomass subject to compliance to these commitments. Aftercare shall be implemented as per the management unit's specific management plan and guidance supplied by the project EMP. If not complied with, the acceptance of biomass will be suspended or cancelled.

14.4 Sharing information, raising awareness, promoting best practice

One of the key factors that could ensure success is a formal effort to convey all the necessary information, partly through the training programme (see Section on Training and Capacity Building below) and partly through a dedicated series of interactions with role players such as organising open days and colloquia. Ideally this should be done in collaboration with existing organizations with similar objectives or functions, e.g. Namibia Biomass Industry Group (N-BIG) and the De-bushing Advisory Service (DAS).

We recommend that an internet-based dashboard should be developed or an existing one expanded (e.g. http://www.dasnamibia.org) as the main form of information sharing amongst stakeholders that are immediately involved in the project (fuel suppliers, MAWF, MET).

Sharing of information to the public and outreach is suggested to be accomplished through the production of pamphlets, posters and a newsletter, presentations at farmer's meetings and the holding of an Open Day once every two years. Additionally, the feasibility of presenting a colloquium every five years should be evaluated, alternatively this could be combined with the Namibia rangeland forum which occurs on an annual basis.

14.5 Training and capacity building

14.5.1 Training is a key to success, and is prescribed by the SEA and national policy

Two key documents that guide bush harvesting are the SEA commissioned by the GiZ project on bush thinning (SAIEA 2016) and the National Rangeland Management Strategy and Policy of the MAWF[20]. Both point out the importance of training of all people involved in bush harvesting, so that labourers 'at the work-face' as well as other fuel supplier staff understand not only which trees to target and which to leave, but also the overall goals that drive the particular management approach and related ecological factors such as why some wood must be left on the veld, the role of fire and the mechanics of the impacts that are being managed. Although not really the mandate of the current project, training should also be directed, where possible, towards Government officials, in both the relevant ministries, MAWF and MET. Training should be done as a starter course for all new participants and as annual refresher courses.

14.5.2 Aspects that need to be addressed

14.5.2.1 Species identification

The risk of cutting down vulnerable, rare or threatened species is one of the most pervasive elements of the impact assessment (see IMPACT 4) and one of the most difficult to manage because it requires a broad spectrum of people to be able to reliably identify several species. This is not an inborn skill and therefore requires dedicated training. We do not foresee a complicated process, because training materials and resources exist in the public domain and it should be easy to pull together a basic course focused on only those species that could occur in the harvesting area. However, it would be advisable to consult an expert botanist in the compiling of the course materials.

14.5.2.2 Savanna ecology

A lot of problems with implementation of any set of management objectives, be they for farming or protected area management, disappear if the people involved understand the system, its drivers and the reasons for the specific approach and management activities. Again, potential training materials already exist in the public domain and courses have been developed for similar reasons (e.g. the course in savanna ecology developed for the park rangers of Namibia's North Eastern Parks). A potential challenge would be to develop a course that is sufficiently practical to capture people's attention while not avoiding the important theoretical basis.

14.5.2.3 Principles of impacts

This aspect is closely related to the previous one but should focus on the impacts defined in the EIA and explain the rationale behind them and the justification for mitigation actions. As such the EIA document and EMP are the main source of training materials, supported by the ecological materials of the previous course. Again, the emphasis should be on a practical demonstration of the issues (e.g., a visit to the Otavi Mountains to survey and understand the high diversity there). This course should include information on the ecological and conservation impacts of poaching and illicit harvesting or

[20] http://www.nrmps.org/

collecting (with an emphasis on rare, threatened or endangered species such as pangolin), and the resources available to prevent it.

14.5.2.4 Aftercare and good rangeland management practises

A crucial aspect of reaching the savanna restoration goal of the project will be how well aftercare programmes are followed and if the causal factors of bush encroachment are effectively minimized through good rangeland management practises in harvested areas. Compiling a practical, comprehensive training manual on best aftercare practises and accompanying training of harvesting staff, land users and farm labourers would go a long way to address these needs. A great aid in this regard would be to include visiting aftercare demonstration plots as part of the training. A starting point with good rangeland management practises would be the NRMPS project, which is currently in the process of compiling a good practises manual for Namibian rangelands.

15 Monitoring

Monitoring is at the core of adaptive management and required by the IFC Standard 6 (IFC 2012). It is designed to provide information on the state of the system as it changes under harvesting towards an open restored savanna state.

There are three basic types of monitoring relevant for the current project (adapted from Hutto & Belote 2013).

1. Process monitoring: This relates to the target activities and tasks that make up the harvesting process. For example, a target area to be cleared will be set for each year and this target needs to be reached. Similarly, the number of non-target trees that were felled should be zero.
2. Compliance monitoring: As part of the implementation governance, each fuel supplier might be expected to commit to the terms of a negotiated EMP. The extent to which they comply to these commitments should be audited by NamPower's EM or a third party through regular inspection of harvesting sites and monitoring of several standard indicators of compliance.
3. Ecological impact/outcomes (biodiversity integrity and productivity) monitoring: At the beginning of the project, research projects should be implemented to define the target savanna condition, the effects of harvesting and the most cost-efficient monitoring indicators. Based on the findings from these studies and in the framework of a refined conceptual model of expected state changes (based on the State and Transition Model of Joubert et al. 2008), a number of indicators of both the ecological integrity and productivity of the restored sites should be measured. These data should then be evaluated against the target savanna condition and the total impact of the project towards the desired outcome of a restored rangeland.

A monitoring framework is suggested in Table 13. This will need to be adapted according to the demands by industry, regulating institutions (e.g. MET, DoF, NamPower itself) and critical issues that may arise in future. It is proposed that the monitoring programme is split in two components where the first deals with the operational before-, during and immediately after harvesting processes and states. This component also monitors the initial aftercare process and its success suggested to be carried out by the fuel supplier. These monitoring actions are required for all management units. This monitoring could potentially be concluded within a year after harvesting, but will depend on the aftercare methods applied (e.g. stump treatment with arboricides has a quicker response than foliar treatment where some regrowth is required before treatment). It is suggested that the responsibilities of the operational monitoring activities are shared by the respective fuel suppliers (subject to auditing) and NamPower, who might choose to source this out to a qualified third party (Table 13).

The second monitoring component looks at longer time frames, starting with a baseline before harvesting and repeated annually thereafter. This monitoring is more quantitative in nature using accepted ecological monitoring methods and sampling designs, but is restricted to a selection of sites situated in different harvesting areas. The purpose of this monitoring is to inform the adaptive management process, evaluate savanna restoration and biodiversity trajectories and, potentially, can also feed into the ECC renewal applications. Site selection should therefore aim to both foster learning for management adaptation, as well as to provide robust information on biodiversity and ecological trends relevant to restoration over time. A powerful monitoring design would be to monitor paired control-treatment sites, where the control represents the non-harvested situation but with comparable environmental traits (similar soils, vegetation species composition and biomass, previous land use) than the paired treated (harvested) site. It is proposed that the responsibility of carrying out the biodiversity monitoring is facilitated by NamPower, who might choose to source the monitoring out to an independent and qualified third party (Table 13).

The Directorate of Forestry should be involved in all monitoring activities.

Table 13. A suggested monitoring framework. A distinction is made between operational monitoring and long-term biodiversity monitoring. An indication of when and who are responsible is also suggested.

Type of monitoring	Indicator	Type of data or units	When	Responsibility
Operational monitoring per harvesting site				
Process monitoring	Size of targeted harvesting area	ha shown on maps	Before harvest	Fuel supplier
	Estimated biomass to harvest	Tons dry mass	Before harvest	Fuel supplier
	Area actually harvested	ha shown on maps	After harvest	Fuel supplier/NamPower
	Biomass actually removed	Tons dry mass	After harvest	Fuel supplier/NamPower
	Fixed point photos	N/A	Before and repeated after harvest	Fuel supplier
Compliance monitoring	Protected plant species impacted	Yes/NO, details of species involved	During harvest/After harvest	NamPower
	Poaching/illegal harvesting incidents	Yes/No, details	During harvest	NamPower
	Signs of pollution	Yes/No, details	During harvest/After harvest	NamPower
	Harvesting on slopes	Yes/No, details	During harvest/After harvest	NamPower
	Harvesting on contours	Yes/No, details	During harvest/After harvest	NamPower
	Disturbances to soil	Yes/No, details	During harvest/After harvest	NamPower
	Post harvesting tree equivalents	Tree equivalents per ha	After harvest	NamPower
Initial aftercare	Aftercare methods used	Description	During harvest/After harvest depending on method	Fuel supplier
	Chemicals and quantities applied	l/ha per arboricides type	After aftercare	Fuel supplier

	Aftercare implementation	Visual inspection/observations	During aftercare	NamPower
	Regrowth rates	# targeted woody plants controlled per m^2	Applicable time after harvesting when aftercare success can be assessed	NamPower
Long-term monitoring in selected sites				
	Rainfall (closest practical)	mm per month	Annually	Nampower
	Events such as fire, frost, insect outbreaks	Description	Annually	Nampower
	Post-harvest land-use including animal stocking rates, grazing/browsing management	Description	Annually	Nampower
	Aftercare effort by landowner	Description	Annually	Nampower
	Fixed point photos	N/A	Annually in May/June	Nampower
	Herbaceous biomass in May/June	kg Dry Matter/ha	Annually in May/June	Nampower
	Herbaceous species composition	% cover per species	Annually in May/June	Nampower
	Woody structure (marked transects)	Woody plant density per species per height class	Annually in May/June	Nampower
	Bare ground	% of land not covered by vegetation or plant litter	Annually in May/June	Nampower
	Severity of soil erosion patterns such as sheet, pedestal, rill, gully, wind deflation/deposits	Estimates on subjective scale	Annually in May/June	Nampower
	Soil carbon %	% soil carbon in top and sub soil layers	Annually	Nampower
	Soil compaction	Compaction of the soil	Annually	Nampower

	Invertebrate species richness and diversity indices (diversity, evenness, similarity)	% trapping success per species	Annually in May/June	Nampower
	Small mammal species richness and diversity indices	% trapping success per species	Annually in May/June	Nampower
	Bird species richness, diversity and similarity indices	Bird recordings per site	Annually in May/June	Nampower
	Large mammal species richness and diversity indices	Dung/track density per species	Annually in May/June	Nampower

16 Research

Key knowledge gaps were described in Section 0. Here we summarise them as three standalone projects, with the first two being critical to the successful management of harvesting and the last one a highly desired but not that critical. We describe each topic in the form of specific postgraduate-level research projects and summarise the rationale, proposed methods, implementation type and expected outputs and outcomes of each.

A very tentative research time frame is proposed below (Figure 28). Given the relatively long life of the project (~25 years, Gordon Gadney pers. comm.), it is not critical to complete the research projects before operations commence, but they should all be done relatively early in the project time line in order to allow maximum opportunity to learn and adapt. Research Project 1 is the main baseline input into the monitoring programme and, as such, the techniques developed should continue in principle for the duration of the project but at a much lower frequency[21].

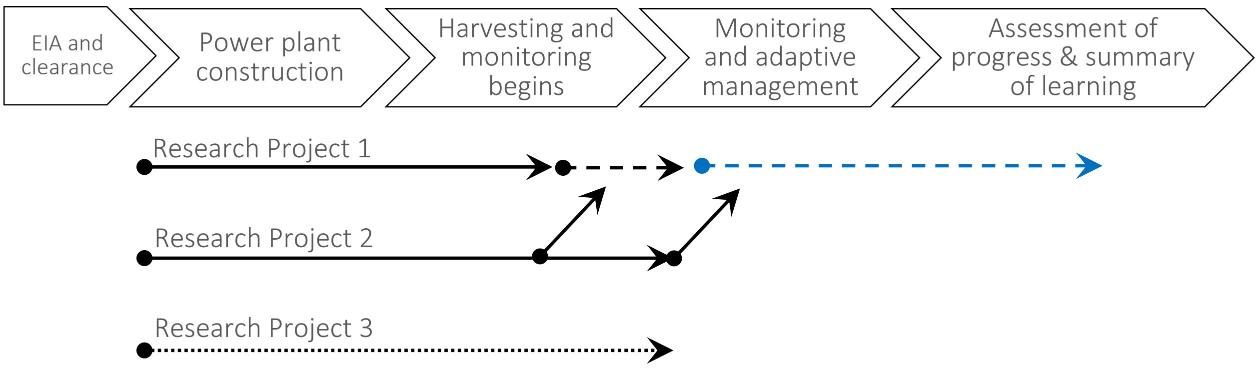


Figure 28. Diagram showing a tentatively proposed timeline for research. Slanted arrows indicate that Project 2 will have results that will be relevant for Project 1 and the monitoring programme. The precise timings of start and finish are not known and not hyper-critical. The dotted blue arrow indicates the advent and operation of the monitoring programme

[21] With much remaining uncertainty about the operational structure of the monitoring and adaptive management that we recommend, it is not possible to imagine the outcomes of the whole process at this stage, but we have in mind a project that delivers as key outputs a basic assessment of the resource, a number of verified indicators and a basic monitoring protocol. These products should then ideally be used by a third party, such as the Geospatial Sciences Department at NUST, to do an annual monitoring event. The scope for this will possibly vary across years but will probably be relatively short duration (a few days to a week each time). Depending on further developments in the sector, potential funding and interest, it might be possible to combine this with the LDN initiative of the MET and extend the assessment to follow-up field-based assessments of carbon and biomass.

16.1 RESEARCH PROJECT 1:

An understanding of the distribution and density of encroaching species at the appropriate scale and the definition of monitoring indicators, an ecological target and the benchmark

Rationale & Objectives: To have a reasonable chance of success at restoration of ecological integrity and productivity and to provide a baseline value against which future monitoring data can be tested, a reliable estimate is needed of the spatial distribution, abundance and density of 1) woody plants in general and 2) encroacher species specifically. In addition, it must be determined what the relationship of their spatial distribution and density, and changes over time in these, are with soil characteristics and spatial rainfall patterns and how these aspects relate to temporal patterns in rainfall (and other climatic variables).

Method: Two main approaches will characterise the project:

i. Using the latest freely available satellite remote sensing data products, maps must be developed to estimate the spatial woody cover at the scale of the harvesting region. This should be accurate enough to determine woody cover per farming unit. Simultaneously, the latest spatial rainfall and soil data must be used as main predictors of patterns in woody density and dynamics of this.
ii. Validation of remote sensing and other spatial digital data (i.e. "ground-truthing") must be done through a systematic fieldwork component. The fieldwork component must simultaneously determine the spatial distribution of the main encroacher species.

Implementation: This is foreseen as a single, three-year PhD.

With the completion of the LDN Pilot Project of the MET (Hengari 2017), some of the objectives of this project could be taken at least in principle from their techniques and in fact it would be important to try and standardise monitoring indicators as much as possible at a national scale. The implication of this is that the project we recommend might not be at a PhD-level and could be downgraded to Masters. On the other hand, the harvesting area for this project differs in many ecological respects from the Otjozondjupa region where the LDN project was implemented, and the conditional skills for such work are beyond a Masters entry level. It would thus still make most sense to define Research Project 1 as a PhD.

Expected outputs and outcomes: This estimate will have at its core a digital map showing relative distributions and densities across the harvesting region and (possibly) predictive maps showing re-growth potential. The results will furthermore be summarised in a PhD thesis, technical reports and scientific publications. Together, these outputs will provide the basis for harvest planning, after-care maintenance and resource projections as well as being the baseline for long-term monitoring.

16.2 RESEARCH PROJECT 2

Understanding of the effects of harvesting on ecological integrity and rangeland productivity

Rationale: Our pilot study on harvesting effects on community integrity of vertebrates and plants, and much other evidence, have shown that the assumption that the removal of the woody component will necessarily result in the desired outcomes for the overall project are false. It is necessary to obtain a better understanding of the differential effects of the harvesting operations on ecological integrity and primary productivity. Effects of harvesting explicitly includes the effects of using arboricides, but this issue needs further unpacking as well (refer to Section 0 in the Baseline Study, this report, for more detail). The topic is large enough to be addressed in a separate project, but for now we leave it in here as part of the ecological component with the proviso that its implementation should again be evaluated at the time.

Method: An extension of the pilot studies to a larger set of variables at more sites. Dependent variables must be the structure and composition of plants, vertebrate and invertebrate communities. Explanatory variables may include *inter alia* soil characteristics, time of harvesting, method of harvesting, after care/maintenance, land use before and after, and others.

Implementation: This is foreseen as an MSc-level project.

Expected outputs and outcomes: Results from this study, summarised in two MSc theses, technical reports and scientific publications, will assist in determining the best management options for long-term successful ecological and agricultural productivity outcomes.

16.3 RESEARCH PROJECT 3

Defining the benchmark: What does the most diverse, resilient and productive savanna look like?

Rationale: To successfully restore an ecosystem, it is necessary to know what the result should look like. In the present case, there are two desired outcomes – ecological integrity and rangeland productivity – that might be achieved with the same end state structure, function and composition, or might not. The proposed project must investigate the relationship of woody cover and its spatial arrangement to biological diversity and grass layer productivity.

Method: This is essentially a field-based survey of the structure function and composition of the plant community on the least dense part of the spectrum. This should comprise both the least encroached remnant habitats and a range of densities in encroached areas that have not been harvested before. Dependent variables will be biological diversity (focusing on both plants and one or more vertebrate or invertebrate taxa). Independent variables will be the density and spatial arrangement (fragmentation, spatial heterogeneity) of woody plants in one or more classes (e.g. shrubs vs trees, encroachers vs non-encroachers).

Implementation: This is foreseen as an MSc-level project.

Expected outputs and outcomes: Results from this study, summarised as an MSc thesis, technical reports and scientific publications, will assist in defining the ecological and productivity targets for the overall project.

17 Best Practice and Guiding Principles for harvesting with ecological restoration objectives

17.1 Introduction

An important recent development has been the publication of the Authorisations Process for Bush Harvesting Projects of the Ministry of Agriculture, Water and Forestry (Pallett & Tarr 2017). This publication is the result of a full strategic environmental assessment process (SAIEA 2016) and is based on sound ecological principles, including the concepts and detail we described in Section 7.11 of the Baseline Study report. **We consider Pallett & Tarr (2017) as an integral part of our recommendations and strongly urge that it should be seen, together with the SEA study of which it is an Appendix (SAIEA 2016), as required reading for all participants in the harvesting process, including NamPower and fuel suppliers.** There is no need to repeat the contents of the publication here, and we therefore take the liberty of attaching it to this report as Appendix 8.

We do however elaborate on some aspects that Pallett & Tarr (2017) deals with only in principle. The guiding principles defined in Pallett & Tarr (2017) are generic and based on broad principles and extensive practice. Since the current project is area-specific, spatially-explicit biodiversity sensitivity could be defined. These sensitivity zones have implications for environmental management, which we describe below. Similarly, for plants at least data on the location of species of concern (endemic and legally protected) exists on a national scale and their overlap with the harvesting area has implications for management. Chief amongst these is the fact that each harvesting project should define its own sensitivity zones before harvesting commences. We discuss these requirements below.

In addition, all specialists involved in the Biodiversity Impact Assessment felt strongly that the basic approach should be one of bush “thinning” as opposed to bush “clearing”. The difference is simple but very important if ecological objectives were to be achieved. And even within this basic concept, there are nuances of approach that may, particularly for certain vegetation types, make the difference between long-term successful restoration of savanna structure and function, and ultimate land degradation. We refer here to the implicit goal of sustainability – harvesting should improve the savanna over the *long-term*, not only until encroaching bush overtakes everything again after harvesting. In this regard, apart from the importance of basic after-care, useful concepts for management are ecological patch dynamics, management of differential competitive advantages that some species might have, the role of fire, and the need to create a heterogeneous mosaic of habitats at a landscape scale.

17.2 The importance of defining spatially explicit biodiversity sensitivity zones

Impacts of harvesting on an area’s biodiversity and ecology vary within the harvesting area. The sensitivity map (Figure 16) is an attempt to indicate at a coarse scale where sensitive areas are located. We recommend that the sensitivity map should be used in conjunction with maps of encroacher species density[22] and is used as a first filter to select potential harvesting zones and specific management units (e.g. farms).

Within management units, a detailed assessment of suitable areas for harvesting, as well as detailed mapping of sensitive/no-go areas and features are recommended. Such a detailed plan should spatially indicate the following biodiversity and ecological features:

- Flora: Areas with high densities of protected plant species, large tree (e.g. >18cm stem diameter at ankle height) populations where harvesting will be difficult to avoid losses of these groups. The harvesting method, size and manoeuvrability of machinery and skill of the operators will also play a role. Known habitats of plant species of conservation importance.
- Fauna: Known breeding places of raptors and vultures.
- Drainage: All drainage lines identifiable on Google Earth with a 100 m buffer on both sides (No-go).
- Topographic: All rocky outcrops, hills and mountainous terrain, all slopes steeper than 12.5 mapped as No-go areas; slopes between 5% and 12.5% as sensitive.
- Soil: Areas where soil erosion signs already occur or where erodible soils are probable.

It is recommended that local ecologists do these assessments, but that specialist inputs are required where harvesting units fall within sensitive zones of the various taxa such as plants, birds, etc.

17.3 Protected plant species and special species sensitivity zones

In the Baseline Study for the current report we identified two special species sensitivity zones. In both cases, these are the only localities where two rare plant species (the orchid *Habenaria amoena* and the geophyte *Brachystelma recurvatum*) have been recorded. As always, it is possible that the species could occur over a wider area as these two localities, but the best data available says they do not. It is therefore best to err on the cautious side and consider these as No-go areas, even if there are harvestable resources available.

Avoid cutting all protected tree species as per Forest Act Regulations of 2015.

17.4 "Clearing" vs "thinning"

Optimum savanna stability, productivity and most benefits for biodiversity, occurs between the extremes of a severe bush encroached and total cleared situation (SAIEA 2016, p.22). For example, higher herbaceous biomass often occurs at a low tree cover, rather than at zero tree cover. Retaining large trees are also important. Especially large *Acacia* trees have been shown to suppress the growth rate of neighbours and to constrain recruitment close to adults (Smit 2004). Large trees and shrubs also create "islands" of fertility through nutrient accumulation underneath crowns.

[22] These maps do not yet exist. We recommend that these should be developed and should be similar to, but with more confident species density estimates than Figure 24 and Figure 25 in the Baseline Study. Such maps should be produced for the adaptive management framework (see the Baseline Study's Section 11.5 on critical knowledge gaps).

Practical guidelines for thinning intensities are provided in the Forestry and Environmental Authorizations Process for Bush Harvesting Projects (Pallett & Tarr 2017). Accordingly, the following post-harvest woody density guidelines apply:

1. Non-sandy substrates where *Acacia* species and/or *Dichrostachys cinerea* are the dominant enchroacher species the total TEs per hectare (all woody plants combined) after harvesting should be at least 1.5 times the average annual rainfall.
2. Sandy substrates where Acacias are the dominant encroacher or where *Colophospermum mopane* is the dominant encroacher (on any substrate) the total TEs per hectare should be at least 2 times the average annual rainfall.
3. Where *Terminalia sericea* is the dominant encroacher species the total TEs per hectare should be at least 3 times the average annual rainfall.
4. In cases where no dominance can be ascribed to a single encroacher species, as well as for encroacher species not mentioned above (e.g. *Terminalia prunioides*) the total TEs after harvesting should be at least 2 times the average annual rainfall.

A quick method to determine the Tree equivalents in a plot is described in the opposite box. Alternatively a photo guide of a range of woody densities can be compiled and used to estimate post-harvest densities in the field. Training should be provided to operators and supervisors how to estimate woody densities.

Box 4: A quick method to estimate Tree Equivalents for a site:

- Select an area with a representative woody density and height distribution.
- Stand in the middle of this area and sum the heights of all woody plants (in meter) within a 5.64 m radius around you.
- Divide the summed heights by 1.5 to get the TEs in the plot.
- Multiply the plot TEs with 100 to get TE/ha.
- Example, there are 1 bush of 1m, 2 bushes of 3m and 1 tree of 5m height within a 5.64 m radius of you = summed height 12m / 1.5 = 8 TEs per plot x 100 = 800 TEs/ha.

Woody plants below 0.5 m height are ignored.

A reference measuring stick for height and measuring tape to determine the radius will make estimates more accurate.

Preferably 3-5 representative sites should be assessed and averaged per area.

Closely related to the aspect of woody density, which is not spatially-specific, is the aspect of the spatial pattern of wood and grass, and the need to leave some woody plant material on the ground after harvesting. Because most ecological processes only have meaning in terms of the spatial arrangement of species and habitats, spatial pattern matters in ecology. Vertical and horizontal heterogeneity creates more niches that support more organisms of different species and ultimately results in a more resilient ecosystem. We therefore recommend that in large harvesting areas (i.e. larger than 25ha) at least one high density thickets of small size (i.e. 30 m diameter) are left to increase the spatial heterogeneity of the harvested area. Similarly, in a natural system, dead trees will fall over and the dead wood will be slowly broken down by decomposers, returning its nutrients to the soil. The physical structure of the deadwood also creates meso- and micro-scale habitats for a range of smaller organisms, further increasing diversity. In this way harvesting removes an important source of nutrients from the system. We therefore recommend that a number of trunks should be left on the ground to provide mulch and nutrients.

17.5 Soil conservation

To prevent soil erosion, no harvesting related activities should take place on slopes steeper than 12.5% (SAIEA 2016). Harvesting on slopes of 5 to 12.5 % are also discouraged and even on gentle slopes cutting and transport machinery should follow the contour. Windrows of felled bushes left to dry out (SLR 2017) should also follow the contour, even on gentle slopes.

17.6 After harvest: preventing woody regrowth to achieve grass-layer productivity

In harvested areas, rapid regrowth of harvested woody plants and woody seedling establishment are to be expected, which need to be controlled to maintain the thinned, stable state and associated ecosystem benefits (Smit et al. 2015). The majority of savanna woody species are able to coppice (regrow from the collar region of the plant) after removal of stems. In addition, the release from tree-on-tree competition often results in a wave of woody reproduction (seedling establishment and probably also root suckers) as demonstrated in the field study (Appendix 7). An effective aftercare programme is therefore deemed essential to keep woody plant densities in harvested areas in check (Dannhauser & Jordaan 2015; Smit et al. 2015; Van Oudtshoorn 2015; Rothauge 2017). This is especially true for the higher rainfall parts of the study area.

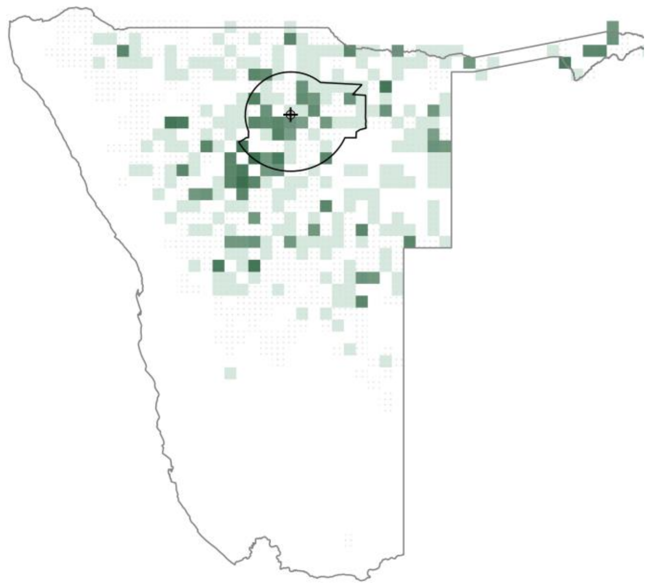


Figure 29. The distribution of D. cinerea *in Namibia. Emphasis has been placed on the quarter degree grid squares where the species has its highest abundance.*

Source: Tree Atlas data, downloaded from www.the-eis.com

How the harvesting is conducted and the harvesting area is managed after harvesting will impact on the effort required to maintain an open woody state. Important natural allies in preventing a resurgence of undesirable woody plants include harvesting in such a way that a good stand of large trees and bushes are retained to help suppress the growth of young woody plants, as well as suppressing the establishment of recruits close to large trees and bushes (Smit et al. 2015). Selective thinning where large trees and bushes are retained, evenly spread over the harvested area, is therefore seen as a crucial component of the harvesting operation. Second, the competitiveness of the herbaceous layer should be encouraged through an effective grazing management system aiming to increase the vigour and competitiveness of perennial grasses (Smit et al. 2015). Managing for a competitive herbaceous layer may take several seasons and will depend on the level of degradation (e.g. perennial grass cover loss), as well as current climatic conditions. Even in the best of cases will these actions not be enough to maintain an open savanna state indefinitely but will result in both fewer woody recruits to be dealt with and will reduce the growth rate of surviving plants in the aftercare programme (Smit et al. 2015). Third, the season when harvesting is conducted appears to affect the subsequent growth and mortality rate of cut woody plants. Strohbach (1998/1999) found that cutting Namibian encroacher species during the rainy season (i.e. January to April) significantly decreased coppice growth rates and also increased the mortality rate of five encroacher species, although the mortality rate of *Dichrostachys cinerea* and *Terminalia sericea* remained low in this experiment, even in the second year of the trial (Strohbach 1998/1999). All three factors mentioned above may slow down the re-infestation rate of the harvested areas, but does not negate the necessity of controlling coppice growth and reproducing woody plants years after the initial harvest event.

Aftercare in the current context deals mainly with the coppice (resprouts) of harvested plants, existing saplings of encroacher species not harvested and emerging woody recruits. It is important that aftercare is not seen as a once off operation (Dannhauser & Jordaan 2015; Smit et al. 2015; Van Oudtshoorn 2015). These undesirable woody plants can be controlled in several ways, which include mechanical, chemical and biological approaches or combinations of these (Van Oudtshoorn 2015; Rothauge 2017).

In mechanical bush control, plants are either physically removed or damaged to such an extent that these plants eventually die (Dannhauser & Jordaan 2015). Seedlings and saplings can be removed manually. Physically removing larger coppiced plants is, however, labour intensive as many encroacher species have to be removed to a depth of at least 20cm below ground (Walter & Volk 1954 in Strohbach 1998/1999). Slashing the aboveground parts is usually ineffective, except when done repeatedly in a single season (i.e. 4 times/annum, Teague & Killilea 1990), and perhaps also in the case of seedlings, which are more vulnerable to physical damage. The use of heavy machinery in aftercare operations is not recommended due to the high soil disturbance and soil compaction expected. One exception might be where the young new growth is cut or mulched and used as roughage in animal feeds (bush-to-feed; Honsbein et al. 2017). In this case it should be kept in mind that the removal of the plants, especially the foliage, will drain the ecosystem of nutrients in the long run (browsing animals, on the other hand, recycle nutrients through dung and urine).

Various chemical herbicides developed to kill shrubs and trees (arboricides; FSC's pesticides) are registered in Namibia for the purpose of controlling encroacher species. Arboricides, however, differ with regards to the mode of application, safety of use and potential environmental impacts. Essentially three application modes can be distinguished. First, soil applied arboricides where the chemical is applied to the soil surface within the root range of target plants. These arboricides dissolve in rain water and are transported to the roots of plants as it infiltrates the soil. The use of soil applied arboricides is generally not recommended in aftercare programmes due to their non-selective nature (arboricides may affect proximate desirable plants) and the risk of leaching from the target area to affect desirable plants (SAIEA 2016). Soil applied arboricides are also not suitable for treating harvested bushes (Smit et al. 2015) and the long-term residual effects of soil applied arboricides has not been well studied in an Namibian context (SAIEA 2016).

Second, stem applied arboricides are applied to the freshly cut/sheared surface of harvested plants as soon as possible after harvesting (i.e. within an hour)(Smit et al. 2015; Van Oudtshoorn 2015). Failure of applying the arboricide according to the specified time can result in poor control of woody plants. Stem applications have the advantage that it is selective, as only the treated plants are controlled. A disadvantage of stem applications is that a percentage of harvested plants would probably die naturally after being harvested; therefore some arboricide will be unintentionally "wasted". Cunningham and Detering (2017) in a Namibian study showed that on average about half of *Senegalia (Acacia) mellifera, Vachellia (Acacia) reficiens* and *Terminalia pruniodes* did not coppice after being cut close to the ground (stem diameter 75-118mm). *Dichrostachys cinerea*, however, coppiced prodigiously, especially on soils with a high clay content (Cunningham & Detering 2017).

Third, the foliage of target plants can be sprayed with a registered arboricide. Foliar control is effective where stem treatment is not feasible, e.g. where stems are broken of (i.e. rolling operations) rather than cut or sheared. To effectively control coppiced plants, the regrowth should be allowed to grow out after harvesting (e.g. 2-10 months; knee to hip height) and the foliage should be green and mostly mature (fully expanded) to ensure good arboricide action (always follow label instructions). Foliar applied arboricides has the advantage that it is also selective and that saplings and seedlings can be effectively controlled (Smit et al. 2015). Unselective spraying using for example tractor boom sprayers will negate the selective advantage and a substantial amount of arboricide may reach the soil surface, therefore should be discouraged. A disadvantage of foliar control is that it is susceptible to drift in windy conditions, thereby potentially harming desirable plants. Therefore only spraying during suitable weather conditions is essential.

A list of arboricides suitable for controlling regrowth of Namibian encroacher species are provided in Van Oudshoorn (2015). In addition, the FSC's list of hazardous pesticides should be frequently consulted as this list is continuously updated as new information becomes available. New developments are also underway and new arboricides may replace or complement the existing registered chemicals in future.

Other approaches to aftercare include the use of periodic fire and/or browsers such as goats. Nevertheless, fire needs thorough planning, preparations and fire-fighting equipment, approval from neighbours and carries the risk that it may spread (SAIEA 2016). Also, to be effective, the fire interval in the harvesting area will probably be every 3-4 years, depending on the rainfall and fuel accumulation. Fire generally kills only seedlings and larger saplings and coppiced plants are only top killed (will coppice again). To minimize damage to desirable larger shrubs and trees, fires for aftercare purposes should be managed to be of intermediate intensity (Rothauge 2017). This can be achieved by burning only during the cool time of the day, when fuel loads are not > 1500kg DM/ha and when the wind is calm. It is always best to burn as far as possible with the wind (some back fires are necessary to contain the fire on the downwind side of the burned area). Burning where *Dichrostachys cinerea* are present should be avoided, because scarification of hard-scaled seeds of species such as *D. cinerea* by fire can facilitate mass germination of dormant seeds. It is possible that fire may have the same effect on other encroacher species with long-lived seeds. The effect of fire can be drastically enhanced if combined with foliar spraying of re-sprouting (coppicing) plants (regrowth must be at least knee high) and seedlings, as well as in combination with intensive browsing, e.g. with goats and/or browsing game (Jordaan & Le Roux undated). Sweet & Mphinyane (1986) cautioned that using goats to control post-fire bush may suppress benign woody species more than spinescent encroacher species such as Vachellia/Senegalia (*Acacia)* species and *Dichrostachys cinerea*. In their experiment in Botswana, the herbaceous layer also suffered with goats. A sufficiently high browsing stocking rate is also required to keep re-sprouting bush under control (Zimmerman & Mwazi 2002). In Botswana a stocking rate of 1 goat/hectare was estimated too lightly stocked to control bush indefinitely (Sweet & Mphinyane 1986). In those parts of the harvesting area that receive relatively higher rainfall, higher stocking rates applied over an extensive period would be required (Zimmerman & Mwazi 2002). The benefit of incorporating browsers in the aftercare programme is that it is a source of additional income for the landowner, but will require considerable management inputs. Browsing game will also benefit from the available browse, but it is more difficult to control stocking rates and their impact on the woody component, therefore should not be relied on as the primary aftercare method.

It is important that the area harvested does not exceed the ability of fuel suppliers to do effective aftercare. Aftercare should be conducted annually for at least three consecutive years, with the first control preferably deployed in the first year after harvesting if stem (immediately after harvesting) or foliar arboricides are used. After three years, the situation can be assessed and an appropriate schedule for further aftercare actions planned. Above average rainfall years may result in mass germination and establishment of encroacher species (Joubert et al. 2008). A contingency plan should be in place to handle such a situation, should it occur.

Aftercare methods differ with regards to the potential impact on the environment, which may be positive or negative. In Appendix 9 these impacts are summarized and suitability recommendations provided from an environmental impact perspective.

Encroacher species have different traits that affect the effort required to control regrowth and recruitment. Especially harvested areas where *Dichrostachys cinerea* (sickle bush) was dominant may be difficult to control (De Wet 2015; SAIEA 2016; Pallett & Tarr 2017) and should be properly planned for in advance. This species is widely distributed in Namibia and at least 19% of those quarter-degree grid squares in which it has been recorded as common to abundant in the Tree Atlas project occur within the harvesting area (Figure 29). Traits that make *D. cinerea* control challenging include the ability to rapidly regrow from disturbed roots (De Wet 2015) and stems (Joubert 2014), the persistent and long-lived seed bank of this species and effective dispersal of seeds by animals (Joubert 2014). *D. cinerea* also tend to be more resistant to soil-applied arboricides than other encroacher species, requiring a higher dose to control (De Klerk 2004). Fortunately, *D. cinerea* is sensitive to current stem and foliar applied arboricides.

17.7 Rangeland management in harvested areas

As pointed out above, the post-harvesting management of the de-bushed rangeland is by far the most important aspect to get right in the quest to restore rangeland ecological integrity and productivity. All the hard work of bush clearing could come undone if sound rangeland management principles are not applied. Fortunately, Namibia's National Rangeland Management Policy and Strategy (NRMPS; MAWF 2012) have defined eight basic principles that comprise best practice for Namibia's arid and semi-arid rangelands.

The eight principles apply to extensive rangeland farming practices across the whole country but have special relevance for post-harvesting management in the current project. The project could in fact make a significant contribution to Namibia's agricultural sector simply by promoting these principles amongst all its fuel suppliers. The principles are:

1. Know your resource base: This includes several aspects of vegetation, such as the difference between annual and perennial grasses, the plant species composition, the condition of the soil surface and the dynamics of the landscape as a multi-level organised adaptive system.
2. Manage for effective recovery and rest: Rest and recovery of plants are applied to make provision for the recovery of perennial grasses and shrubs, build-up of organic matter, the development of a drought reserve, and to ensure maximum seed production and establishment of seedlings.

3. Manage for effective utilisation of plants (grasses and shrubs): Defoliation of only half of the grass plant during the growing season allows the plant to stay in the active growth phase, meaning that less root reserves are needed to start regrowth and more plant material can be produced in the shortest possible time.
4. Enhancing soil condition: Grazing ecosystems have strong interactions between soil and vegetation – soil that is in a good condition can support vegetation that in turn protects the soil and provides fodder for grazing animals and organic material which maintains soil fertility.
5. Addressing bush encroachment: The suppressing effects of bush encroachment on rangeland productivity are well known. In terms of the current project, it is particularly important that post-harvest care and maintenance must be tight.
6. Drought planning: In Namibia it is not a question whether drought will occur, but when it will occur. Planning for drought is therefore crucial and includes aspects such as making provision for a "spare camp" or key resource area, planting pastures and/or drought-resistant fodder crops (in areas with > 500 mm rain pa) and making hay from natural grass lands. Additionally, new early warning systems allow farmers to reduce stock levels timeously and prevent economic and ecological crises when drought surprises them.
7. Monitoring of the resource base: Monitoring is an essential part of sound management of natural systems. Aspects that should be monitored include rangeland condition, numbers and types of livestock, water resources (above- and below-ground) and climate.
8. Planning land use infrastructure: Infrastructure developments on the farm should be planned to enable the application of the rangeland principles, with the most important being the provision of water points at strategic places.

More detail can be found in the NRMPS, which is available for download from the website of Restoring Namibia's Rangelands[23].

[23] http://www.nrmps.org/p/documents.html

18 Bibliography

Alexander, G. & Marais, J. 2007. A guide to the reptiles of southern Africa. Struik Publishers (Pty) Ltd, Cape Town.

Barnard, P. (ed.) 1998. Biological diversity in Namibia: a country study. Windhoek: Namibian National Biodiversity Task Force.

Ben-Shahar, R. 1992. The effects of bush clearance on African ungulates in a semi-arid nature reserve. Ecological Applications, 2(1), 95-101.

Bester, F.V. 1996. Bush encroachment – a thorny problem. Namibia Environment. (1). ISBN -86976'372-5 Ed. Peter Tarr. Ministy of Environment and Tourism.

Bester, F.V. 1998. Major problem-bush species and densities in Namibia. Agricola 1998/1999.

Birch, C., Harper-Simmonds, L., Lindeque, P., and Middleton, A. 2016. The Economics of Land Degradation Initiative: Practitioner 's Guide for sustainable land management.

Blanc, J. 2008. *Loxodonta africana*. The IUCN Red List of Threatened Species 2008: e.T12392A3339343. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T12392A3339343.en. Downloaded on 17 March 2018.

Blaum, N., Rossmanith, E., Jeltsch, F. 2007a. Land use affects rodent communities in Kalahari savannah rangelands. African Journal of Ecology, 45(2):189–195. https://doi.org/10.1111/j.1365-2028.2006.00696.x

Blaum, N., Rossmanith, E., Popp, A., Jeltsch, F. 2007b. Shrub encroachment affects mammalian carnivore abundance and species richness in semiarid rangelands. Acta Oecologica, 31(1):86–92. https://doi.org/10.1016/j.actao.2006.10.004

Bond, W. J., & Midgley, J. J. 2001. Ecology of sprouting in woody plants: the persistence niche. Trends in ecology & evolution, 16(1), 45-51.

Bond, W.J. 2008. What limits trees in C4 grasslands and savannas? Annual Review of Ecology, Evolution and Systematics, 39:641-659.

Branch, W. R., 1998. Field guide to snakes and other reptiles of southern Africa.

Buyer, J. S., & Maul, J. E. 2016. Soil microbial communities following bush removal in a Namibian savanna. Soil, 2(1):101.

Chidumayo, E. N., Kwibisa, L. 2003. Effects of deforestation on grass biomass and soil nutrient status in miombo woodland, Zambia. Agriculture, ecosystems & environment, 96(1), 97-105.

Coetzee, M.E. 2003. Characteristics of Namibian soils in a nutshell. Spotlight on Agriculture, Volume 65.

Craven P. 2002. Phytogeography of Namibia: A taxon approach to the spermatophyte flora. Masters thesis, University of Stellenbosch.

Craven P., Vorster P. 2006. Patterns of plant diversity and endemism in Namibia. Bothalia, 36(2):175-179.

Craven, P., Loots, S. 2004. *Gazania thermalis*. The IUCN Red List of Threatened Species 2004: e.T46765A11080950. http://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T46765A11080950.en. Downloaded on 08 June 2017.

Cunningham, P. L., & Detering, F. (2017). Determining age, growth rate and regrowth for a few tree species causing bush thickening in north-central Namibia. Namibian Journal of Environment, 1, A-76.

Curtis, B., Mannheimer, C. A. 2005. Tree Atlas of Namibia. National Botanical Research Institute, Windhoek.

Dannhauser, C., Jordaan, J. 2015. Practical Veld and Pasture Management for Farmers. Kejafa Knowledge Works, Krugersdorp.

De Klerk, J.N. 2004. Bush Encroachment in Namibia. Report on Phase 1 of the Bush Encroachment Research, Monitoring and Management Project. Ministry of Environment and Tourism, Windhoek, Namibia.

De Wet, M.J. 2015. Harvesting Namibian encroacher bush. Compedium of harvesting technologies for encroacher bush in Namibia. Support to De-bushing Project, GIZ.

Dean, W. R. J., Milton, S. J., & Jeltsch, F. 1999. Large trees, fertile islands, and birds in arid savanna. Journal of Arid Environments, 41(1), 61-78.

Donaldson, C. H. 1969. Bush encroachment with special reference to the blackthorn problem of the Molopo area. Department of Agricultural Technical Services.

du Toit, J. T. 2003. Large herbivores and savanna heterogeneity. The Kruger experience: Ecology and management of savanna heterogeneity, 292-309.

Durant, S., Mitchell, N., Ipavec, A., Groom, R. 2015. *Acinonyx jubatus*. The IUCN Red List of Threatened Species 2015: e.T219A50649567. http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T219A50649567.en. Downloaded on 17 March 2018.

Eccard, J. A., & Ylönen, H. 2003. Interspecific competition in small rodents: from populations to individuals. Evolutionary Ecology, 17(4), 423-440.

Emslie, R. 2012. *Ceratotherium simum*. The IUCN Red List of Threatened Species 2012: e.T4185A16980466. http://dx.doi.org/10.2305/IUCN.UK.2012.RLTS.T4185A16980466.en. Downloaded on 17 March 2018.

Fick SE, Hijmans RJ, 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology. http://worldclim.org/version2.

Gebrekirstos, A., Mitlöhner, R., Teketay, D., Worbes, M. 2008. Climate–growth relationships of the dominant tree species from semi-arid savanna woodland in Ethiopia. Trees, 22(5), 631-641.

Giess W. 1998. A preliminary vegetation map of Namibia Dinteria 4: 5-114.

Gordon, I. J., & Prins, H. H. 2008. Introduction: grazers and browsers in a changing world. In: The ecology of browsing and grazing (pp. 1-20). Springer, Berlin, Heidelberg.

Griffin, M. 2003. Annotated checklist and provisional conservation status of Namibian reptiles. Namibia Scientific Society.

Hammer, Ø., Harper, D.A.T., Ryan, P.D. 2008. PAST-palaeontological statistics, ver. 1.89. Paleontological Museum, University of Oslo, Noruega.(También disponible en línea: http://folk. uio. no/ohammer/past/index. html).

Hengari, S. 2017. Implementing Land Degradation Neutrality in Otjozondjupa region, Namibia 2/2016 to 3/2017. Final report. Unpublished report to the Ministry of Environment and Tourism, Windhoek.

Higgins, S. I., Bond, W. J., & Trollope, W. S. 2000. Fire, resprouting and variability: a recipe for grass–tree coexistence in savanna. Journal of Ecology, 88(2), 213-229.

Hilliard OM. 1994. The Manuleae – a tribe of the Scrophulariaceae. Edinburgh University Press, Edinburgh.

Hoffman, M.T., Schmiedel, U., Jürgens, N. (eds.) 2010. Biodiversity in southern Africa 3: Implications for landuse and management. Göttingen & Windhoek: Klaus Hess Publishers.

Honsbein, D., Shiningavamwe, K.L., Iikela, J., De la Puerta Fernandez, M.L. 2017. From encroacher bush to animal feed. MAWF/GIZ Support to De-bushing Project.

Honsbein, D., Swart, W., & Lubbe, L. 2012. Evaluation on possible environmental effects of the generic arboricides Tebuthiuron and Bromacil under Namibian conditions. Consultancy report for the Meat Board of Namibia.

Hudak, T., Wessman, C., Seastedt, T.R. 2003. Woody overstorey effects on soil carbon and nitrogen pools in South African savanna, Austral Ecology, 28(2), pp. 173–181. doi: 10.1046/j.1442-9993.2003.01265.x.

Hutto, R.L., Belote, R.T. 2013. Distinguishing four types of monitoring based on the questions they address. /Forest Ecology and Management 289, 183–189.

IFC 2012. Performance Standard 6 Biodiversity Conservation and Sustainable Management of Living Natural Resources. International Financial Corporation – World Bank Group.

Institute of Applied Ecology (IEA) 1998. AMD African Mammals Databank - A Databank for the Conservation and Management of the African Mammals Vol 1 and 2. Report to the Directorate-General for Development (DGVIII/A/1) of the European Commission. Project No. B7-6200/94-15/VIII/ENV. Bruxelles 1998. pp 1174

International Finance Corporation (IFC) 2012. Performance Standard and Guideline Notes 2012. Available at: www.ifc.org

Irish J. 1994. Biomes of Namibia. Navorsings van die Nasionale Museum (South Africa), 10: 550-84.

Irish, J. 2018. Biomass Power Project: Invertebrates Baseline study. Unpublished Specialist Report, this study.

Jordaan, J., Le Roux, A. Undated. Die invloed van vuur, boerbokke en beeste op die houtagtige component van dei suuragtige gemengde bosveld. Interanl report, Towoomba Livestock Development Centre, South Africa.

Joubert, D. F. 2014. The dynamics of bush thickening by *Acacia mellifera* in the highland savanna of Namibia, pp. 145. PhD thesis.

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

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

Joubert, D.F. Zimmermann, I. 2002. The potential impacts of wood harvesting of bush thickening species on biodiversity and ecological processes. Proceedings of the First National Forestry Research Workshop held on 12 and 13 March 2002 in Windhoek, Namibia, Ministry of Environment and Tourism, Forestry Publication 9:67-78.

Karuaera, N. A. 2011. Assessing the effects of bush encroachment on species abundance, composition and diversity of small mammals at the Neudamm Agricultural Farm, Khomas Region Namibia (Doctoral dissertation).

King, S.R.B., Moehlman, P.D. 2016. *Equus quagga*. The IUCN Red List of Threatened Species 2016: e.T41013A45172424. http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T41013A45172424.en. Downloaded on 17 March 2018.

Klaassen E., Craven P. 2003. Checklist of Grasses in Namibia. Southern African Botanical Diversity Network Report No. 20. SABONET, Pretoria and Windhoek.

Klaassen E.S., Kwembeya, E.G. (eds). 2013. A Checklist of Namibian Indigenous and Naturalised Plants. Occasional Contributions No. 5, National Botanical Research Institute, Windhoek, Namibia.

Kottek, M., Grieser, J., Beck, C., Rudolf, B. Rubel, F. 2006. World Map of the Köppen-Geiger climate classification updated. Meteorologische Zeitschrift, 15, 259-263.

Le Roux, P. J., Müller, M. A. N., Curtis, B., & Mannheimer, C. (2009). Le Roux and Müller's field guide to the trees & shrubs of Namibia. Macmillan Education Namibia.

Lindsey, P. A., Balme, G., Becker, M., Begg, C., Bento, C., Bocchino, C., Lewis, D. 2013. The bushmeat trade in African savannas: Impacts, drivers, and possible solutions. Biological conservation, 160, 80-96.

Maggs, G.L, Craven, P., Kolberg, H.H. 1998. Plant species richness, endemism, and genetic resources in Namibia. Biodiversity and Conservation 7, 435-446.

Marais, J. 2004. A Complete Guide to the Snakes of Southern Africa. Cape Town, South Africa. Struik Nature.

Meik, J. M., Jeo, R. M., Mendelson Iii, J. R., & Jenks, K. E. 2002. Effects of bush encroachment on an assemblage of diurnal lizard species in central Namibia. Biological Conservation, 106(1), 29-36.

Mendelsohn J., Jarvis A., Roberts C., Robertson T. 2002. Atlas of Namibia. A portrait of the land and its people. David Philip Publishers, Cape Town, RSA.

Mickleburgh, S., Hutson, A.M., Bergmans, W., Cotterill, F.P.D. 2008. *Hipposideros vittatus*. The IUCN Red List of Threatened Species 2008: e.T135485A4129766. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T135485A4129766.en. Downloaded on 17 March 2018.

Ministry of Agriculture Water and Forestry (MAWF) 2012. National Rangeland Management Policy and Strategy. MAWF, Windhoek, Namibia.

Muller, Z., Bercovitch, F., Brand, R., Brown, D., Brown, M., Bolger, D., Carter, K., Deacon, F., Doherty, J.B., Fennessy, J., Fennessy, S., Hussein, A.A., Lee, D., Marais, A., Strauss, M., Tutchings, A., Wube, T. 2016. *Giraffa camelopardalis* (errata version published in 2017). The IUCN Red List of Threatened Species 2016: e.T9194A109326950. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T9194A51140239.en. Downloaded on 17 March 2018.

National Herbarium of Namibia (WIND). 2011. SPMNDB/BRAHMS Database. National Herbarium of Namibia (WIND), National Botanical Research Institute, MAWF, Windhoek, Namibia.

Nijbroek, R. 2016. Pilot Project Land Degradation Neutrality, Namibia: Establishment of a baseline for land degradation in the region of Otjozondjupa. Unpublished Annexure to the Namibian LDN Pilot Project in the Otjozondjupa Region (Hengari 2017). Ministry of Environment and Tourism, Windhoek.

NNF 2016. Regional assessment of the economics of land degradation related to bush encroachment in Otjozondjupa, Namibia. Unpublished report to the GiZ, Windhoek, Namibia.

Novellie, P. 2008. *Equus zebra*. The IUCN Red List of Threatened Species 2008: e.T7960A12876787. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T7960A12876787.en. Downloaded on 17 March 2018.

O'Connor, T. G., Puttick, J. R., & Hoffman, M. T. 2014. Bush encroachment in southern Africa: changes and causes. African Journal of Range & Forage Science, 31(2), 67-88.

Pallett, J., & Tarr, P. 2017SAIEA (The Southern African Institute for Environmental Assessment). 2017. Forestry and Environmental Authorisations Process for Bush Harvesting Projects. Guidelines for complying with regulations governing bush thinning and value addition projects. Ministry of Agriculture, Water and Ministry of Environment and Tourism.

Pietersen, D., Waterman, C., Hywood, L., Rankin, P., Soewu, D. 2014. *Smutsia temminckii*. The IUCN Red List of Threatened Species 2014: e.T12765A45222717. http://dx.doi.org/10.2305/IUCN.UK.2014-2.RLTS.T12765A45222717.en. Downloaded on 17 March 2018.

Pringle, H., Zimmerman, I., Tinley, K. 2011. Accelerating landscape incision and the downward spiralling rain use efficiency of Namibian rangelands. Agricola, 43 – 52

Rothauge, A. 2017. Bush Control Manual. Support to De-bushing Project – GIZ, John Meinert Printing, Windhoek.

SAIEA (The Southern African Institute for Environmental Assessment). 2016. Strategic Environmental Assessment of large-scale bush thinning and value-addition activities in Namibia: Final report. Unpublished report for the MAWF/GIZ Support to De-bushing Project.

Sankaran, M., Hanan, N.P., Scholes, R.J., et al. 2005. Determinants of woody cover in African savannas. Nature, 438, 846-849.

Sankaran, M., Ratnam, J. and Hanan, N. P. 2008. Woody cover in African savannas: the role of resources, fire and herbivory. Global Ecology and Biogeography, 17, 236–245.

Sankaran, M., Ratnam, J., & Hanan, N. P. 2004. Tree–grass coexistence in savannas revisited–insights from an examination of assumptions and mechanisms invoked in existing models. Ecology letters, 7(6), 480-490.

Scholes, R.J. 1990. The influence of soil fertility on the ecology of southern African savannas. Journal of Biogeography, 17, 415-419.

Scholes, R.J., Archer, S.R. 1997. Tree-grass interactions in savannas. Annual Review of Ecology and Systematics, 28, 517–44.

Scholes, R.J., Bond, W.J., Eckhardt, H.C. 2003. Vegetation dynamics in the Kruger ecosystem. Chapter 11 in: Du Toit, J.T., Rogers, K.H. & Biggs, H.C. (eds.) The Kruger Experience: Ecology and Management of Savanna Heterogeneity. Island Press, Washington D.C.

Scholes, R.J., Walker, B.H. 1993. An African savanna – Synthesis of the Nylsvley Study. Cambridge University Press, Cambridge, MA.

Scott, A., Scott, M. 2018. Environmental Impact Assessment for the proposed Encroacher Bush Biomass Power Project in Namibia: Avifauna impact assessment. Unpublished Specialist Report, this study.

Sheuyange, A., Oba, G., Weladji, R.B. 2005. Effects of anthropogenic fire history on savanna vegetation in northeastern Namibia. Journal of Environmental Management 75, 189–198.

Sirami, C., Seymour, C., Midgley, G., & Barnard, P. 2009. The impact of shrub encroachment on savanna bird diversity from local to regional scale. Diversity and Distributions, 15(6), 948-957.

Sliwa, A., Wilson, B., Küsters, M., Tordiffe, A. 2016. *Felis nigripes*. The IUCN Red List of Threatened Species 2016: e.T8542A50652196. http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T8542A50652196.en. Downloaded on 17 March 2018.

SLR. 2017. The European Investment Bank and NamPower EIA for the proposed encroacher bush biomass power project in Namibia . Background Information document.

SLR. 2018. Soil Impact Assessment for the Proposed Encroacher Bush Biomass Power Project in Namibia. Unpublished Specialist Report, this study. SLR Project No.: 7NA.05062.00002.

Smit, G. N. 2001. The influence of tree thinning on the vegetative growth and browse production of Colophospermum mopane. South African Journal of Wildlife Research-24-month delayed open access, 31(3-4), 99-114.

Smit, G. N. 2004. An approach to tree thinning to structure southern African savannas for long-term restoration from bush encroachment. Journal of Environmental Management, 71(2), 179-191.

Smit, G.N., De Klerk, J.N., Schneider, M.B. & Van Eck, J. 2015 Quantifying harvestable encroacher bush – Determining the balance between environmental sustainability and economic feasibility of bush utilization in Namibia. GIZ, John Meinert Printing, Windhoek.

Stein, A.B., Athreya, V., Gerngross, P., Balme, G., Henschel, P., Karanth, U., Miquelle, D., Rostro-Garcia, S., Kamler, J.F., Laguardia, A., Khorozyan, I., Ghoddousi, A. 2016. *Panthera pardus* (errata version published in 2016). The IUCN Red List of Threatened Species 2016: e.T15954A102421779. http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T15954A50659089.en. Downloaded on 17 March 2018.

Strohbach, B. J. 2012. Providing relevant, useful information on Namibian vegetation types. Agricola, 7–39.

Strohbach, B.J. 1998/1999. The effect of season and treatment on the survival rate and coppicing ability of five encroacher species – I: The effect of felling heights. Agricola 1998/1999)99-105.

Sweet R. J., W. Mpinyane. 1986. Preliminary observations on the ability of goats to control post-burning regrowth in Acacia nigrescens/Combretum apiculatum savanna in Botswana. Journal of Grassland Society of Southern Africa 3:79–84

Teague, W. R., & Killilea, D. M. 1990. The effect of ringbarking Brachystegia spiciformis Benth., Julbernardia globiflora (Benth.) Troupin and Terminaliasericea Burch. ex DC. trees at different heights with or without the addition of a pidoram/2, 4-D mixture. Journal of the Grassland Society of Southern Africa, 7(3), 157-165.

Tews, J., Brose, U., Grimm, V., Tielbörger, K., Wichmann, M. C., Schwager, M., & Jeltsch, F. 2004. Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. Journal of biogeography, 31(1), 79-92.

Underwood, A.J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications, 4, 3-15.

United Nations 1992. Convention on Biological Diversity (CBD). Available at: http:www.biodiv.org/default.aspx (accessed April 2014).

Van Oudtshoorn, F. 2015. Veld management: principles and practices. Briza.

Ward, D. 2005. Do we understand the causes of bush encroachment in African savannas? African Journal of Range & Forage Science 22(2), 101–105.

Wiegand, K., Saltz, D., Ward, D. 2006. A patch-dynamics approach to savanna dynamics and woody plant encroachment – Insights from an arid savanna. Perspectives in Plant Ecology, Evolution and Systematics, 7(4), 229–242. doi: 10.1016/j.ppees.2005.10.001.

Wiesel, I. 2015. *Parahyaena brunnea*. The IUCN Red List of Threatened Species 2015: e.T10276A82344448. http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T10276A82344448.en. Downloaded on 17 March 2018.

Woodroffe, R., Sillero-Zubiri, C. 2012. *Lycaon pictus*. The IUCN Red List of Threatened Species 2012: e.T12436A16711116.

Zimmermann, I., & Mwazi, F. N. 2002. The effect of a prescribed burn, followed up with browsing pressure, on rangeland condition in the mountain savanna and karstveld of Namibia. Dinteria, 27: 49-57.

Zimmermann, I., Nghikembua, M., Shipingana, D., Aron, T., Groves, D., & Marker, L. 2017. The influence of two levels of debushing in Namibia's Thornbush Savanna on overall soil fertility, measured through bioassays. Namibian Journal of Environment, 1, A-59.

Appendix 1: Woody species of conservation concern (endemic, near-endemic and Red Data) recorded in the various vegetation zones (Red Data species in red).

Species	Protected by Forest Act 12 of 2001, as amended in 2005 and the 2015 regulations (Government Gazette No. 5801).	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Acacia erioloba E.Mey.	1				Widespread, overharvested for fuel-wood.	1	1	1	1
Adansonia digitata L.	1				Rare in the study area, far more common elsewhere in Namibia. Valuable habitat and tourism resource.	1	1		1
Adenium boehmianum Schinz	1		LC		More common further west than in study area. Likely to be heavily impacted by indiscriminant mechanical harvesting. Vulnerable to illegal collection for horticultural purposes.	1	1		1
Albizia anthelmintica (A. Rich.) Brongn.	1				Widespread.	1	1	1	1
Baikiaea plurijuga Harms	1		NT		Widespread, overharvested, valuable timber species.			1	

Species	Protected by Forest Act 12 of 2001, as amended in 2005 and the 2015 regulations (Government Gazette No. 5801).	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Berchemia discolor (Klotzsch) Hemsl.	1				Reasonably widespread. Valuable fruit species. Fruit can be dried and stored and provides nutritional diversity in the dry season as well as a cash crop.	1	1	1	1
Boscia albitrunca (Burch.) Gilg & Gilg-Ben.	1				Widespread. Fruit important for fauna. Foliage highly nutritious browse.	1	1	1	1
Burkea africana Hook.	1		LC		Widespread, overharvested, valuable timber species.	1	1	1	1
Colophospermum mopane (J.Kirk ex Benth.) J.Kirk ex J.Léonard	1		LC		Widespread, should not be harvested where not encroaching. Does not encroach in the study area. Host to edible caterpillar (eaten by humans and other fauna).	1	1	1	1
Combretum imberbe Wawra	1				Widespread, but very slow-growing, subject to illegal harvest for charcoal and timber. Likely to become of increasing concern country-wide. Of religious value to some groups.	1	1	1	1

Species	Protected by Forest Act 12 of 2001, as amended in 2005 and the 2015 regulations (Government Gazette No. 5801).	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Cyphostemma juttae (Dinter & Gilg) Desc.	1		V		Restricted range, subject to illegal collection, occurs on ridges, koppies, mountains.	1			1
Dialium englerianum Henriq.					Multi-use species, food, medicinal.			1	
Elephantorrhiza schinziana Dinter			DD		Restricted distribution, uncommon. Found on rocky slopes and plains.	1			1
Erythrina decora Harms	1		LC		Widespread but never common. Mainly mountains and koppies species.	1			1
Faidherbia albida (Delile) A.Chev.	1		LC		Found in riparian areas.	1			
Ficus cordata Thunb. subsp. cordata	1		LC		Widespread. Important fruit tree.	1	1		1
Ficus petersii Warb. (=Ficus thonningii)	1		LC		Widespread. Important shade and fruit tree	1	1		1
Ficus sycomorus L. subsp. gnaphalocarpa (Miq.) C.C.Berg	1		LC		Widespread. Important shade and fruit tree (esp for humans). Often occurs in "stands" of large, aged trees where water table is shallow.	1	1		1

Species	Protected by Forest Act 12 of 2001, as amended in 2005 and the 2015 regulations (Government Gazette No. 5801).	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Gubourtia coleosperma (Benth.) J.L¬Çonard	1				Very important food, cash crop, timber and shade tree.			1	
Kirkia acuminata Oliv.					Previously protected but reasonably common and quite wide range, so removed from list. Large scale impacts will change its conservation status. Most common on Ridges/Mountains but also occurs on plains.	1		1	
Lannea discolor (Sond.) Engl.	1				Reasonably widespread but concentrated mainly in the Karstveld. Edible fruit. Medicinal uses.	1		1	1
Maerua schinzii Pax	1		LC		Very widespread. Valuable browse.	1	1	1	1
Moringa ovalifolia Dinter & A.Berger	1		LC		Widespread. Subject to illegal collecting.	1	1		
Pachypodium lealii Welw.	1		LC	1	Reasonably widespread, subject to illegal collecting. Occurs on koppies and mountains.	1	1		1

Species	Protected by Forest Act 12 of 2001, as amended in 2005 and the 2015 regulations (Government Gazette No. 5801).	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Pterocarpus angolensis DC.	1		NT		Widespread but severely threatened by overharvesting for timber and wood-carving.	1		1	
Schinziophyton rautanenii (Schinz) Radcl.-Sm.	1				Widespread. Extremely valuable edible fruit kernel, also used to produce valuable edible oil. Cash crop species for rural people.	1		1	
Sclerocarya birrea (A.Rich.) Hochst. subsp. caffra (Sond.) Kokwaro	1				Widespread, valuable fruit tree	1	1	1	1
Searsia lancea (L.f.) F.A.Barkley	1				Widespread. Important to retain river banks.	1	1	1	1
Spirostachys africana Sond.	1				Reasonably widespread, was heavily impacted for mining props in the Karstveld, millions of trees harvested. This loss is thought to have been a major driver of the widespread bush encroachment in the area at present. Very valuable timber species.	1	1	1	1

Species	Protected by Forest Act 12 of 2001, as amended in 2005 and the 2015 regulations (Government Gazette No. 5801).	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Sterculia africana (Lour.) Fiori var. africana	1		LC		Widespread. Occurs mainly on ridges, koppies and mountains.	1	1		
Strychnos cocculoides Baker	1				Important fruit tree. Cash crop. Often diameter < 18 cm.	1		1	
Strychnos pungens Soler.	1				Important fruit tree. Cash crop. Often diameter < 18 cm.			1	
Ziziphus mucronata Willd. subsp. mucronata	1				Widespread, common. Important to retain river banks and river beds. Fruit an important resource for fauna.	1	1	1	1
TOTAL	25	0		1		26	17	21	21
Endemic									
Near-endemic									
Red Data Categories: DD = Data deficient, precautionary principle applies; LC = Least concern; V = Vulnerable; NT = Near threatened									

Appendix 2: Non-woody species of conservation concern (protected, endemic, near-endemic and Red Data) recorded in the various vegetation zones (Red Data species in red).

Species	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Acrotome fleckii (Gürke) Launert				Very widespread annual.	1		1	
Aloe dinteri A.Berger	1		1	Restricted and disjunct distribution, mostly outside of study area.		1		
Aloe hereroensis Engl.	1	LC	1	Widespread, subject to illegal collection.	1			
Aloe littoralis Baker	1			Widespread, subject to illegal collection.	1	1	1	1
Aloe zebrina Baker	1	LC	1	Widespread.	1		1	
Ammocharis nerinoides (Baker) Lehmiller				Restricted and disjunct distribution. Recorded from farm Heidelberg, north of Tsumeb. Likely to occur in calcrete area.	1			
Antiphiona pinnatisecta (S.Moore) Merxm.				Widespread.	1		1	1
Aspilia eenii S.Moore				Reasonably widespread.	1			
Barleria kaloxytona Lindau				Reasonably widespread, but concentrated in Karstveld. Mostly plains species. Likely to be affected in high numbers by mechanical harvesting.	1	1		
Barleria lanceolata (Schinz) Oberm.		LC		Widespread.	1			1
Brachystelma mafekingense N.E.Br.				Widespread. Has subterranean rootstock.	1		1	1
Brachiaria schoenfelderi C.E.Hubb. & Schweick.				Little known. Grass.	1		1	1
Brachystelma recurvatum Bruyns	1	DD		Little known. One record from Farm Harasib, south of Tsumeb.	1			
Ceropegia carnosa E.Mey.	1	LC		Relatively widespread. Has subterranean rootstock.	1		1	
Ceropegia crassifolia Schltr.	1	R		Occasional. Has subterranean rootstock.	1			
Ceropegia dinteri Schltr.	1	LC		Relatively widespread, uncommon. Has subterranean rootstock.	1			

Species	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Ceropegia lugardiae N.E.Br.	1	LC		Reasonably widespread and common. Has subterranean rootstock.	1		1	1
Ceropegia multiflora Baker subsp. tentaculata (N.E.Br.) H.Huber forma tentaculata	1	LC		Reasonably widespread and common. Has subterranean rootstock.	1			
Ceropegia nilotica Kotschy var. nilotica	1	LC		Reasonably widespread and common. Has subterranean rootstock.	1		1	1
Ceropegia stenoloba Hochst. ex Chiov.	1	LC		Restricted distribution. Has subterranean rootstock.	1		1	1
Commicarpus decipiens Meikle		LC			1			
Crassocephalum coeruleum (O.Hoffm.) R.E.Fr.		LC		Almost entirely confined to the Waterberg-Karst area. Likely to be heavily affected. Probably already badly affected by poisoning. Habitats various	1			
Crassula lanceolata (Eckl. & Zeyh.) Endl. ex Walp. subsp. transvaalensis (Kuntze) Toelken	1	LC		Widespread.	1			
Cyphostemma omburense (Gilg & M.Brandt) Desc.		LC		Few scattered records, appears to be quite widespread.	1			
Cyphostemma puberulum (C.A.Sm.) Wild & R.B.Drumm.		DD		Poorly known.	1		1	
Dactyliandra welwitschii Hook.f.		LC		Widespread.	1		1	1
Duvalia polita N.E.Br. var. parviflora (L.Bolus) A.C.White & B.Sloane	1	LC		Reasonably widespread. Likely to be affected by large scale mechanical harvesting.	1		1	
Eragrostis scopelophila Pilg.				Widespread. Grass.	1			
Eulophia speciosa (R.Br. ex Lindl.) Bolus	1	LC		Reasonably widespread. Geophyte.	1		1	1
Euphorbia spartaria N.E.Br.		DD		Reasonably widespread.	1			
Euphorbia venenata Marloth		DD		Restricted range.	1		1	1

Species	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Euphorbia volkmanniae Dinter		DD		Highly restricted range. Koppies/mountains	1			
Geigeria odontoptera O.Hoffm.		LC		Reasonably widespread, common.	1	1	1	
Habenaria amoena Summerh.	1			Only known from a single record near Otavi.	1			
Heteromorpha stenophylla Welw. ex Schinz var. stenophylla				Only known from the dolomite hills around Tsumeb.	1			
Hibiscus fleckii Gürke				Widespread.	1	1		
Hibiscus sulfuranthus Ulbr.				Few, scattered records. Unlikely to be of concern, probably under-recorded.	1			
Hiernia angolensis S.Moore		LC		Widespread.	1		1	1
Huernia oculata Hook.f.	1			Reasonably widespread. Plains species. Likely to be heavily affected by large scale mechanical harvesting.	1		1	
Indigofera hochstetteri Baker subsp. streyana (Merxm.) A.Schreib.				Widespread, common.	1			
Jamesbrittenia dolomitica Hilliard				Highly restricted distribution, Karstveld only, Hill/Mountain species.	1			
Jamesbrittenia fragilis (Pilg.) Hilliard				Highly restricted distribution, Karstveld only, Hill/Mountain species.	1			
Kohautia azurea (Dinter & K. Krause) Bremek.		LC		Reasonably widespread.	1		1	
Monechma tonsum P.G.Mey.		LC		Reasonably widespread.		1	1	1
Orbea lugardii (N.E.Br.) Bruyns	1	DDT		Reasonably widespread			1	
Ornithogalum rautanenii Schinz		LC		Reasonably widespread although already impacted by B2 Gold and Navachab. Common on limestone plains. Geophyte.	1	1		
Ornithoglossum calcicola K.Krause & Dinter		LC		Widespread, limestone habitats only, common on ridges and hills as well as stony plains. Geophyte.	1	1		1

Species	Protected by Nature Conservation Ordinance No. 4 of 1975, including amendments	IUCN Red Data Status (only species of concern listed)	CITES Appendix ii	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Pelargonium otaviense R.Knuth		LC		Reasonably widespread, seldom common, usually on koppies.	1			
Petalidium rautanenii				Restricted distribution. Limestone species. Common on koppies and mountains as well as plains.	1	1		
Plectranthus dinteri Briq.		LC		Restricted distribution, often locally common. Koppies/Mountains	1			
Pteronia eenii S.Moore		LC		Restricted distribution, but reasonably common. Calcareous plains.	1		1	1
Ruelliopsis damarensis S.Moore				Poorly recorded.			1	
Stapelia kwebensis N.E.Br.	1	LC		Widespread. Mainly plains species. Likely to be affected by large scale mechanical clearing. Subject to illegal collection.	1		1	1
Stapelia schinzii A.Berger & Schltr. var. schinzii	1	DD		Reasonably widespread, seldom common. Plains, koppies and ridges. Subject to illegal collection.	1		1	1
Stigmatorhynchus hereroensis Schltr.		LC		Restricted distribution but more commonly known from Etosha and eslewhere.	1		1	1
Thesium xerophyticum A.W.Hill	1	LR-nT		Restricted, disjunct distribution. Hill species.	1		1	1
	17		3		52	9	27	19

Endemic

Near-endemic

Red Data Categories: DD = Data deficient, precautionary principle applies; LC = Least concern; V = Vulnerable; LRnT = Low Risk Near Threatened

Appendix 3: Other species of potential concern, which are not protected, endemic, near-endemic or Red Data species

Species	Notes	Karstveld	Mopane Savanna	Kalahari Woodlands	Thorn tree and shrub Savanna
Combretum collinum Fresen.	Important timber and shade species.			1	
Combretum psidiodes Welw.	Seldom reaches 18 cm diameter			1	
Grewia spp.	Important fruit resource for fauna.	1	1	1	1
Gyrocarpus americanus Jacq. subsp. africanus Kubitzki	Restricted distribution.	1			
Hyphaene petersiana Klotzsch ex Mart.	Important fruit and sap tree, fruit used for carving.	1		1	
Kirkia acuminata Oliv.	Keystone species of the Otavi Highlands. Fast growing. Common on slopes.	1	1	1	1
Olea europaea L. subsp. africana (Mill.) P.S.Green	Evergreen, often multi-stemmed, will be missed by stem diameter restrictions.	1		1	1
Ozoroa insignis Delile	Much of its range in Namibia is included in the proposed harvesting area. Often many-stemmed, stems way under 18 cm			1	
Peltophorum africanum Sond.	Important source of wood.	1	1	1	1
Philenoptera nelsii (Schinz) Schrire	Multi-use species, Leaves and flowers are important browse. Bee tree. Wood multi-purpose.	1	1	1	1
Securidaca longepedunculata Fresen.	Important multi-use medicinal species			1	
Ximenia americana L.	Important fruit resource for fauna.	1		1	
Ximenia caffra Sond. var. caffra	Important fruit resource for fauna.	1	1	1	

Appendix 4: A Amphibian species expected at the Otjikoto site and in the harvesting area with indication of the conservation (IUCN). No amphibian species are protected according to the Nature Conservation Ordinance of Namibia or CITES.

Species	Common name	Site	Harvesting area	IUCN	Endemic/Rare
Breviceps adspersus	Bushveld Rain Frog	Yes	Yes	Least Concern	
Cacosternum boettgeri	Boettger's Caco	Yes	Yes	Least Concern	
Hildebrandtia ornata	Ornate Frog	Yes	Yes	Least Concern	
Kassina senegalensis	Bubbling Kassina	Yes	Yes	Least Concern	
Phrynobatrachus mababiensis	Dwarf Puddle Frog	Yes	Yes	Least Concern	
Phrynobatrachus natalensis	Snoring Puddle Frog	No	Yes	Least Concern	
Phrynomantis affinis	Spotted Rubber Frog	Yes	Yes	Least Concern	Rare
Phrynomantis bifasciatus	Banded Rubber Frog	Yes	Yes	Least Concern	
Poyntonophrynus damaranus	Damaraland Pygmy Toad	No	Yes	Data Deficient	Endemic
Poyntonophrynus dombensis	Dombe Pygmy Toad	No	Yes	Least Concern	Endemic
Pyxicephalus adspersus	Giant Bullfrog	Yes	Yes	Least Concern	
Sclerophrys gutturalis	Guttural Toad	Yes	Yes	Least Concern	
Sclerophrys poweri	Western Olive Toad	Yes	Yes	Least Concern	
Sclerophrys pusilla	Flat-backed Toad	Yes	Yes	Least Concern	
Tomopterna krugerensis	Knocking Sand Frog	Yes	Yes	Least Concern	
Tomopterna tandyi	Tandy's Sand Frog	Yes	Yes	Least Concern	
Xenopus laevis	Common Platanna	Yes	Yes	Least Concern	
Xenopus petersii	Peters' Platanna	No	Yes	Least Concern	

Appendix 5: Reptile species expected at the Otjikoto site and in the harvesting area with indication of the conservation (IUCN) and legal status according to the Nature Conservation Ordinance of Namibia and CITES.

Scientific name	Common name	Otjikoto site	Harvesting area	IUCN	Endemic/ Rare	Namibia Nature Regulations	Cites
Acontias percivali occidentalis	Western legless skink	Yes	Yes	Least concern			
Agama aculeata	Common ground agama	Yes	Yes	Least concern			
Amblyodipsas ventrimaculata	Kalahari purple-glossed snake	Yes	Yes	Least concern			
Aspidelaps lubricus	Coral snake	No	Yes	Least concern			
Aspidelaps scutatus	Shield-nose snake	Yes	Yes	Least concern			
Atractaspis bibronii	Southern stiletto snake	Yes	Yes	Least concern			
Bitis arietans	Puff adder	Yes	Yes	Least concern			
Bitis caudalis	Horned adder	Yes	Yes	Least concern			
Chamaeleo dilepis	Flap-neck chameleon	Yes	Yes	Least Concern			
Cordylus jordani	Namibian girdled lizard	No	Yes	Least concern	Endemic		
Dalophia pistillum	Blunt-tailed worm lizard	No	Yes	Least concern			
Dasypeltis scabra	Rhombic egg eater	Yes	Yes	Least concern			
Dendroaspis polylepis	Black mamba	Yes	Yes	Least concern			
Dispholidus typus	Boomslang	Yes	Yes	Least concern			
Elapsoidea semiannulata	Angola garter snake	Yes	Yes	Least concern			
Elapsoidea sundevallii fitzsimonsi	Kalahari garter snake	Yes	Yes	Least concern			
Stigmochelys (=Geochelone) pardalis	Leopard tortoise	Yes	Yes	Least concern		Protected	Appendix II
Gerrhosaurus multilineatus auritus	Kalahari plated lizard	Yes	Yes	Least concern			
Gerrhosaurus nigrolineatus	Black-lined plated lizard	Yes	Yes	Least concern			

Scientific name	Common name	Otjikoto site	Harvesting area	IUCN	Endemic/ Rare	Namibia Nature Regulations	Cites
Heliobolis lugubris	Bushveld lizard	Yes	Yes	Least concern			
Ichnotropis capensis	Cape rough-scaled lizard	Yes	Yes	Least concern			
Ichnotropis squamulosa	Common rough-scaled lizard	Yes	Yes	Least concern			
Lamprophis capensis	Brown house snake	Yes	Yes	Least concern			
Leptotyphlops labialis	Damara worm snake	Yes	Yes	Least concern	Endemic		
Leptotyphlops scutifrons	Peters' worm snake	Yes	Yes	Least concern			
Lycophidion capense	Cape wolf snake	Yes	Yes	Least concern			
Lygodactylus bradfieldi	Namibian dwarf gecko	Yes	Yes	Least concern	Endemic		
Lygosoma sundevalli	Common writhing skink	Yes	Yes	Least Concern			
Mehelya capensis	Cape file snake	Yes	Yes	Least concern			
Monopeltis anchietae	Angolan spade-snouted worm snake	Yes	Yes	Least concern			
Monopeltis infuscata	Dusky spade-snouted worm snake	No	Yes	Least concern			
Monopeltis sphenorhynchus mauricei	Slender spade-snouted worm snake	Yes	Yes	Least concern			
Naja nigricollis nigricincta	Western barred spitting cobra, zebra snake	No	Yes	Least concern	Endemic (near)		
Naja anchietae	Angolan cobra	Yes	Yes	Least concern			
Naja mossambica	Mozambique spitting cobra	Yes	Yes	Least concern			
Nucras holubi	Holub's sandveld lizard	No	Yes	Least concern			
Nucras intertexta	Spotted sandveld lizard	No	Yes	Least concern			
Pachydactylus capensis	Cape gecko	Yes	Yes	Least concern			
Pachydactylus punctatus	Speckled gecko	Yes	Yes	Least concern			
Pachydactylus turneri	Tropical button-scale gecko	Yes	Yes	Least concern			
Pachydactylus weberi	Weber's gecko	No	Yes	Least concern			
Pedioplanis lineoocellata	Spotted sand lizard	No	Yes	Least concern			
Pedioplanis namaquensis	Namaqua sand lizard	Yes	Yes	Least concern			

Scientific name	Common name	Otjikoto site	Harvesting area	IUCN	Endemic/ Rare	Namibia Nature Regulations	Cites
Pelomedusa subrufa	Helmeted terrapin	Yes	Yes	Least concern			
Prosymna bivittata	Twin-striped shovel-snout snake	No	Yes	Least concern			
Prosymna frontalis	South-western shovel-snout snake	No	Yes	Least concern	Endemic		
Psammobates oculiferus	Serrated tent tortoise	Yes	Yes	Vulnerable[1]		Protected	Appendix II
Psammophis angolensis	Dwarf whip snake	Yes	Yes	Least concern			
Psammophis jallae	Jalla's sand snake	Yes	Yes	Data Deficient			
Psammophis leopardinus	Leopard whip snake	No	Yes	Least concern	Endemic		
Psammophis mossambicus	Olive whip snake	Yes	Yes	Least concern			
Psammophis notostictus	Karoo whip snake	No	Yes	Least concern			
Psammophis subtaeniatus	Western striped-bellied sand	Yes	Yes	Least concern			
Psammophis trinasalis	Kalahari sand snake	Yes	Yes	Least concern			
Psammophylax tritaeniatus	Striped skaapsteker	Yes	Yes	Least concern			
Pseudaspis cana	Mole snake	Yes	Yes	Least concern			
Ptenopus garrulus	Common barking gecko	No	Yes	Least concern			
Python natalensis	Southern African python	Yes	Yes	Vulnerable[1]		Protected	Appendix II
Rhinotyphlops boylei	Kalahari blind	No	Yes	Least concern			
Rhinotyphlops schlegelii petersii	Schlegel's blind	Yes	Yes	Least concern			
Telescopus semiannulatus semiannulatus	Southern tiger snake	Yes	Yes	Least concern			
Trachylepis acutilabris	Wedge-snouted skink	No	Yes	Least concern			
Trachylepis varia	Common variable skink	Yes	Yes	Least concern			
Trachylepis variegata	Western variegated skink	No	Yes	Least concern			
Trachylepis wahlbergii	Wahlberg's striped skink	Yes	Yes	Least concern			
Typhlacontias rohani	Kalahari legless burrowing skink	No	Yes	Least concern			
Typhlosaurus lineatus	Striped blind legless skink	No	Yes	Least concern			
Varanus albigularis	Veld leguaan (monitor)	Yes	Yes	Vulnerable		Protected Game	Appendix II

Scientific name	Common name	Otjikoto site	Harvesting area	IUCN	Endemic/ Rare	Namibia Nature Regulations	Cites
Xenocalamus bicolor	Variable quill-snouted snake	Yes	Yes	Least concern			
Xenocalamus mechowii	Elongated quill-snouted snake	Yes	Yes	Least concern			
Zygaspis quadrifrons	Kalahari round-headed worm	Yes	Yes	Least concern			

[1] According to Griffin (2003)

Appendix 6: Mammal species expected at the Otjikoto site and in the harvesting area with indication of the conservation (IUCN) and legal status according to the Nature Conservation Ordinance of Namibia and CITES.

Species	Common name	Otjikoto site	Harvesting area	IUCN category	Endemic	Nature Conservation Ordinance	CITES category
Acinonyx jubatus	Cheetah	Yes	Yes	Vulnerable		Protected	Appendix I
Aepyceros melampus	Impala	No	Yes	Least Concern		Spec. Protected	
Aethomys chrysophilus	Red Rock Rat	Yes	Yes	Least Concern			
Alcelaphus buselaphus caama	Red hartebeest	Yes	Yes	Least Concern		Protected	
Antidorcas marsupialis	Springbok	Yes	Yes	Least Concern			
Atelerix frontalis	Hedgehog	No	Yes	Least Concern		Protected	
Canis mesomelas	Black-backed Jackal	Yes	Yes	Least Concern			
Caracal caracal	Caracal	Yes	Yes	Least Concern			Appendix II
Ceratotherium simum	White Rhino	Yes	Yes	Near Threatened		Spec. Protected	Appendix I
Chaerephon chapini	Long-crested Free-tailed Bat	No	Yes	Least Concern			
Chaerephon nigeriae	Nigerian Free-tailed Bat	Yes	Yes	Least Concern			
Civettictis civetta	African Civet	No	Yes	Least Concern			
Connochaetes taurinus	Blue Wildebeest	Yes	Yes	Least Concern		Protected	
Crocidura cyanea	Reddish-grey Musk Shrew	No	Yes	Least Concern			
Crocidura fuscomurina	Bicolored Musk Shrew	Yes	Yes	Least Concern			
Crocidura hirta	Lesser Red Musk Shrew	No	Yes	Least Concern			
Crocidura olivieri	Olivier's Shrew	No	Yes	Least Concern			
Crocuta crocuta	Spotted Hyaena	Yes	Yes	Least Concern			

Species	Common name	Otjikoto site	Harvesting area	IUCN category	Endemic	Nature Conservation Ordinance	CITES category
Cynictis penicillata	Yellow Mongoose	Yes	Yes	Least Concern			
Damaliscus lunatus	Tsessebe	No	Yes	Least Concern		Protected	
Desmodillus auricularis		Yes	Yes	Least Concern			
Diceros bicornis	Black Rhino	Yes	Yes	Critically Endangered		Spec. Protected	Appendix I
Elephantulus intufi	Bushveld Sengi	Yes	Yes	Least Concern	Endemic		
Equus quagga	Plains Zebra	Yes	Yes	Near Threatened			
Equus zebra	Mountain Zebra	No	Yes	Vulnerable	Endemic	Spec. Protected	Appendix II
Felis nigripes	Black-footed Cat	Yes	Yes	Vulnerable			Appendix I
Felis silvestris	African Wild Cat	Yes	Yes	Least Concern			Appendix II
Fukomys damarensis	Damara Mole Rat	Yes	Yes	Least Concern			
Funisciurus congicus	Congo Rope Squirrel	Yes	Yes	Least Concern			
Galago moholi	Bushbaby	Yes	Yes	Least Concern		Protected	Appendix II
Genetta genetta	Common Genet	Yes	Yes	Least Concern			
Genetta maculata	Large-spotted Genet	Yes	Yes	Least Concern			
Gerbilliscus brantsii	Highveld Gerbil	Yes	Yes	Least Concern			
Gerbilliscus leucogaster	Bushveld Gerbil	Yes	Yes	Least Concern			
Gerbillurus paeba	Hairy-footed Gerbil	Yes	Yes	Least Concern			
Giraffa camelopardalis	Giraffe	Yes	Yes	Vulnerable		Spec. Protected	
Glauconycteris variegata	Variegated Butterfly Bat	No	Yes	Least Concern			
Graphiurus microtis	Small-eared Dormouse	No	Yes	Least Concern			

Species	Common name	Otjikoto site	Harvesting area	IUCN category	Endemic	Nature Conservation Ordinance	CITES category
Helogale parvula	Common Dwarf Mongoose	No	Yes	Least Concern			
Herpestes flavescens	Kaokoveld Slender Mongoose	No	Yes	Least Concern	Endemic/Rare		
Herpestes ichneumon	Egyptian Mongoose	No	Yes	Least Concern			
Herpestes sanguineus	Common Slender Mongoose	Yes	Yes	Least Concern			
Hipposideros vittatus	Commerson's Leafnosed Bat	Yes	Yes	Near Threatened			
Hippotragus equinus	Roan Antelope	Yes	Yes	Least Concern		Protected	
Hystrix africaeaustralis	Cape Porcupine	Yes	Yes	Least Concern			
Ictonyx striatus	Striped Polecat	Yes	Yes	Least Concern			
Lemniscomys rosalia	Single-striped Grass Mouse	Yes	Yes	Least Concern			
Leptailurus serval	Serval	Yes	Yes	Least Concern			Appendix II
Lepus victoriae	African Savanna Hare	Yes	Yes	Least Concern			
Loxodonta africana	Elephant	No	Yes	Vulnerable		Spec. Protected	Appendix II
Lycaon pictus	Wild Dog	No	Yes	Endangered		Spec. Protected	
Madoqua kirkii	Damara dik-dik	Yes	Yes	Least Concern		Protected	
Malacothrix typica	Gerbil Mouse	No	Yes	Least Concern			
Mastomys coucha	Southern Multimammate Mouse	Yes	Yes	Least Concern			
Mastomys natalensis	Natal Multimammate Mouse	Yes	Yes	Least Concern			

Species	Common name	Otjikoto site	Harvesting area	IUCN category	Endemic	Nature Conservation Ordinance	CITES category
Mellivora capensis	Honey Badger	Yes	Yes	Least Concern		Protected	
Micaelamys namaquensis	Namaqua Rock Rat	Yes	Yes	Least Concern			
Mungos mungo	Banded Mongoose	Yes	Yes	Least Concern			
Mus indutus	Desert Pygmy Mouse	Yes	Yes	Least Concern			
Mus setzeri	Setzer's Pygmy Mouse	No	Yes	Least Concern			
Neoromicia capensis	Cape Bat	Yes	Yes	Least Concern			
Neoromicia zuluensis	Zulu Pipistrelle Bat	Yes	Yes	Least Concern			
Nycteris thebaica	Cape Long-eared Bat	Yes	Yes	Least Concern			
Nycticeinops schlieffeni	Schlieffen's Bat	No	Yes	Least Concern			
Oreotragus oreotragus	Klipspringer	Yes	Yes	Least Concern		Spec. Protected	
Orycteropus afer	Antbear	Yes	Yes	Least Concern		Protected	
Oryx gazella	Gemsbok	Yes	Yes	Least Concern			
Otocyon megalotis	Bat-eared Fox	Yes	Yes	Least Concern		Protected	
Panthera leo	Lion	No	Yes	Vulnerable			Appendix II
Panthera pardus	Leopard	Yes	Yes	Vulnerable		Protected	Appendix I
Papio ursinus	Baboon	Yes	Yes	Least Concern			Appendix II
Paracynictis selousi	Selous's Mongoose	No	Yes	Least Concern			
Parahyaena brunnea	Brown Hyaena	Yes	Yes	Near Threatened			
Paraxerus cepapi	Smith's Bush Squirrel	Yes	Yes	Least Concern			

Species	Common name	Otjikoto site	Harvesting area	IUCN category	Endemic	Nature Conservation Ordinance	CITES category
Pedetes capensis	Spring Hare	Yes	Yes	Least Concern			
Petromus typicus	Dassie Rat	No	Yes	Least Concern	Endemic		
Petromyscus shortridgei	Shortridge's Rock Mouse	Yes	Yes	Least Concern			
Phacochoerus africanus	Warthog	Yes	Yes	Least Concern			
Pipistrellus rusticus	Rusty Pipistrelle Bat	Yes	Yes	Least Concern			
Procavia capensis	Rock Hyrax	Yes	Yes	Least Concern			
Pronolagus randensis	Jameson's Red Rock Hare	No	Yes	Least Concern			
Proteles cristata	Aardwolf	Yes	Yes	Least Concern		Protected	
Raphicerus campestris	Steenbok	Yes	Yes	Least Concern		Protected	
Redunca arundinum	Reedbuck	No	Yes	Least Concern		Protected	
Rhabdomys pumilio	Four-striped Grass Mouse	Yes	Yes	Least Concern			
Rhinolophus damarensis	Darling’s horsehoe bat	Yes	Yes	Least Concern			
Rhinolophus denti	Dent's Horseshoe Bat	Yes	Yes	Least Concern			
Rhinolophus fumigatus	Rüppell's Horseshoe Bat	Yes	Yes	Least Concern			
Saccostomus campestris	Southern African Pouched Mouse	Yes	Yes	Least Concern			
Scotophilus dinganii	African Yellow House Bat	Yes	Yes	Least Concern			
Scotophilus leucogaster	White-bellied Yellow Bat	No	Yes	Least Concern			
Smutsia temminckii	Pangolin	Yes	Yes	Vulnerable		Protected	Appendix I
Steatomys pratensis	Fat Mouse	Yes	Yes	Least Concern			

Species	Common name	Otjikoto site	Harvesting area	IUCN category	Endemic	Nature Conservation Ordinance	CITES category
Sylvicapra grimmia	Common Duiker	Yes	Yes	Least Concern		Protected	
Syncerus caffer	Buffalo	No	Yes	Least Concern			
Thallomys nigricauda	Black-tailed Tree Rat	Yes	Yes	Least Concern			
Thallomys paedulcus	Acacia Rat	No	Yes	Least Concern			
Tragelaphus oryx	Eland	Yes	Yes	Least Concern		Protected	
Tragelaphus strepsiceros	Kudu	Yes	Yes	Least Concern			
Vulpes chama	Cape Fox	Yes	Yes	Least Concern		Protected	
Xerus inauris	South African Ground Squirrel	No	Yes	Least Concern			
Zelotomys woosnami	Woosnam's Broad-headed Mouse	Yes	Yes	Least Concern	Rare		

Appendix 7 *The effects of harvesting on community structure of selected savanna sites*

An addendum report to the Biodiversity Baseline and Impact Assessment study for Nampower's Encroacher Bush Biomass Power Project

By Cornelis van der Waal & Theo Wassenaar

Introduction

Thicket formation, or bush encroachment, is a form of land degradation that is particularly prevalent in the semi-arid savannas of north-eastern and eastern Namibia. The high density of similar-aged stands of often multi-stemmed shrubs prevents the formation of a diverse and productive grass layer, decreases the groundwater re-charge rate and alters the species composition and function of the savanna ecosystem.

Such effects of encroachment are not merely of academic interest. Sustainable production of livestock and game on these extensive rangelands intimately depends on an intact, resilient and biologically diverse savanna ecosystem. By decreasing the structural and compositional heterogeneity and, through that, also negatively affecting functional processes such as water and nutrient flows, bush encroachment leads to significant negative effects on the potential for animal production.

The need for corrective action, through improved grazing management and through physical reduction of woody dominance of the vegetation has long been recognised. Appropriate management will not only improve the potential productivity of the rangelands but will also support a significant part of Namibia's biological diversity, as well as enhancing other ecological services.

In general, bush encroachment has received its fair share of scientific attention, but surprisingly few studies have tested the underlying hypothesis that the removal of woody biomass will result in restoration (which we loosely define as more resilient, productive and diverse savannas), nor to determine which approach will come closest to this goal.

In this study we attempt to contribute to the understanding of woody biomass removal and the effects this has on 1) herbaceous biomass productivity, 2) plant species diversity and community structure and 3) wild large herbivore community structure.

Methods

General approach and study areas

To gain a better understanding of the potential effects of large-scale woody biomass harvesting on an area's biodiversity and ecological functioning, field research was conducted. The research entails the comparison of areas previously harvested for the Ohorongo cement factory with on-site control sites where no woody biomass harvesting took place. The comparisons were conducted at three different farms located in Namibian savannas, two of which are within the 100km harvesting radius of the Otjikoto site. The farm Gabus is located northwest of Otavi, the farm Tirol south of Otavi and the Cheetah Conservation Fund's property east of Otjiwarongo. Field data collection took place from 2 to 10 July 2017.

Selecting sites

Sampling sites selection was aided by maps of the study units showing woody biomass. The woody biomass estimates were based on satellite derived synthetic aperture radar data (Japanese Space Agency's ALOS PALSAR mosaic data Horizontal-Vertical polarization) for 2015. The radar backscatter values reflect live, woody biomass in non-rocky areas. During a subsequent site visit, sites were selected where the different treatments were in close proximity (i.e. 300-500m) of each other to minimize bias due to non-treatment factors. The treatments consisted of 1) woody harvesting where the wood has been removed, 2) control areas where no harvesting took place and 3) previously harvested areas that have been chemically or physically maintained in an open state. The CCF property did not have any maintained areas; therefore the study design was not balanced in terms of treatment replications. In selecting sites, a gradient of time since harvesting was also constructed after consultations with land managers and owners.

Vegetation sampling

Descending point surveys were conducted to determine the plant species composition at sites. Transects 100m long were laid out and the intersection of all projected plant canopies (as seen from above) per point were recorded per species at 1m intervals along the transect.

Belt transects were used to determine the species composition, density and height structure of woody vegetation per site. All woody plants rooted within 1m of the transect rope were considered. In cases of thick stemmed individuals, more than half of stem (or stems if multi-stemmed) should be within the belt transect to be included. The following were recorded per individual woody plant, including woody seedlings:

1. Species
2. Height of tallest live part of canopy.
3. Phenology of leaves retained on plants (dried out and green) in the following classes:
   - 0 No leaves (plant must be alive)
   - 1 1-10% of full leaf carriage
   - 2 11-40% of full leaf carriage
   - 3 41-70% of full leaf carriage
   - 4 70-100% of full leaf carriage
4. Record if pods/seeds or flowers are present
5. Status of plant:
   a. Healthy
   b. Dead
   c. Coppice
   d. Die-back of branches and stem/s (more than 25% affected)

The woody layer (all woody plants taller than 4m) was sampled using a wandering quarter (WQ) method (Catana 1963) (**Figure 2**), in which a sequence of measurements is obtained through a population by starting at a randomly selected point (in this case the origin of the plot) and choosing the nearest individual within a 90° angle of inclusion around a previously chosen compass azimuth. Another 90° angle of inclusion is then constructed with the last individual as a vertex and the compass bearing as a bisector. The distance to the nearest individual within this angle is then measured, continuing this procedure for 25 distance measurements through the sampling area along each of four transects. In this study, where precision was less critical and sampling limited by the time available, this was adapted to a single transect measuring 10 individuals. Density (n/ha) is calculated as a function of mean distance between individuals. Each individual plant was identified to species level and its height and two diameter measurements along the widest and thinnest horizontal dimensions respectively taken. The abundance of woody plants was measured as the actual volume (height x length x width), standardized to the maximum measured value.

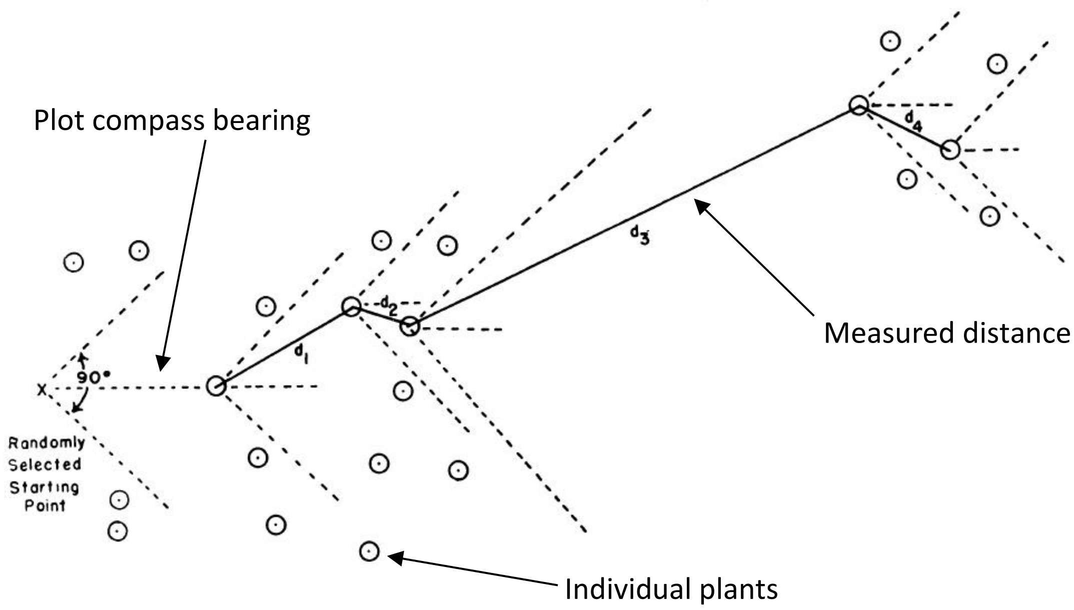


Figure 1. A diagram depicting the operation of the Wandering Quarter method of estimating population density of aggregated sessile organisms (adapted from Catana 1963).

In this diagram the small circles represent individual plants and the solid lines are measurements of distances. A randomly selected starting point is chosen (in our case this was the same point as used for the origin of the herbaceous sampling plot) and the distance to the closest individual woody shrub or tree within a 90° angle of inclusion bisected by the original compass bearing (represented in the diagram above by the dotted line linking the first two individuals) is measured. At that individual plant, the procedure is repeated to the next closest individual and so on until 10 individuals have been measured.

Standing herbaceous biomass was quantified per site using a double sampling technique (Haydock & Shaw 1975). Accordingly the observer marks three reference patches with coloured flags representing low to high biomass. These are awarded scores 1-3 and used as reference for subsequent biomass estimates. Along a transect (100m) a 1 x 1 m quadrate is placed at 5 meter intervals and the herbaceous biomass scored keeping the reference patches in mind. After scoring all 20 quadrates along the transect, three random calibration quadrates where the observer can confidently award a score are clipped and later dried (70^0 at 48 hours in drying oven) and weighed. The calibration quadrates are then used per site to calculate a mean dry matter mass/score value, which is used to calculate the mean herbaceous biomass per plot for the 20 scored quadrates. Al herbaceous biomass values were reported as kg dry matter per ha.

The use of harvested and control areas by mammals was estimated from dung and other sign surveys. All large mammal dung piles, burrows made by animals such as gerbils, aardvark, etc., and other signs indicating the presence of mammals (such as tracks) in belt transects of 4m x 100m were recorded. Direct sightings of large herbivores during field work were also recorded.

Statistical analyses

Plant species diversity indices were calculated using the PAST 3.16 software (Hammer et al. 2008).

Herbaceous biomass differences between treatments were analysed with a General Linear Model (GLM) in IBM SPSS (version 22) or Statistica software. The herbaceous biomass and woody plant density were logarithmically (natural) transformed before entering in statistical models. Farm (CCF, Gabus and Tirol) was entered as a random factor in GLM models.

Woody plant density was logarithmically (natural) transformed.

Results

Herbaceous biomass

Herbaceous biomass differed between treatments (GLM, $F_{2,18} = 15.025$, P<0.001) and study units ($F_{2,18} = 15.637$, P<0.001). When controlling for differences between study units, herbaceous biomass was highest in areas where woody cover is maintained in an open state, followed by harvesting and removal of woody biomass (Figure 2). Control areas, as expected, had the lowest biomass (Figure 2).

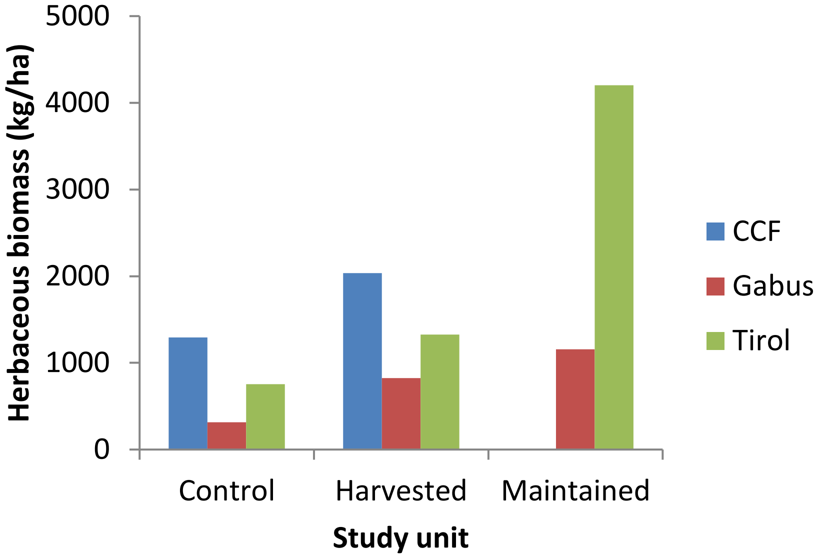


Figure 2 A comparison of the herbaceous biomass between study units and treatments. Maintained refer to sites where the biomass was harvested and the site then maintained in an open state.

Woody plant responses to harvesting

Overall woody plant density differed between treatments (GLM, $F_{2,18}=7.884$, P<0.01). Woody density in harvested areas (mean, 4010 plants/ha) was higher (Tukey, P<0.05) than maintained areas (mean, 938 plants/ha). Neither harvested nor maintained woody density was significant different from controls (2929 plants/ha, Tukey, P>0.05).

The height distribution of woody plants differed between treatments (Figure 3). The density of seedling and saplings (0-0.5 m height) was highest (GLM, $F_{2,18}=10.479$, P<0.01) in the harvested (2065 plants/ha) and lowest in the maintained treatment plots (517 plants/ha), with control sites intermediate (795 plants/ha)(Figure 3). Differences between treatments in the 0.5-1m followed the same pattern ($F_{2,18} = 5.636$, P<0.05). The woody density in the 1-2m height stratum was, however, not different (GLM, P>0.05)(Figure 3). Woody density differed between treatments in the 2-3m stratum ($F_{2,18} = 11.706$, P<0.05). In contrast to the lower strata, control densities were higher (Tukey, P<0.05) than both harvested and maintained treatments, which did not differ from each other (P>0.05). Woody density in the > 3m height stratum did not differ between treatments (GLM, P>0.05)(Figure 3).

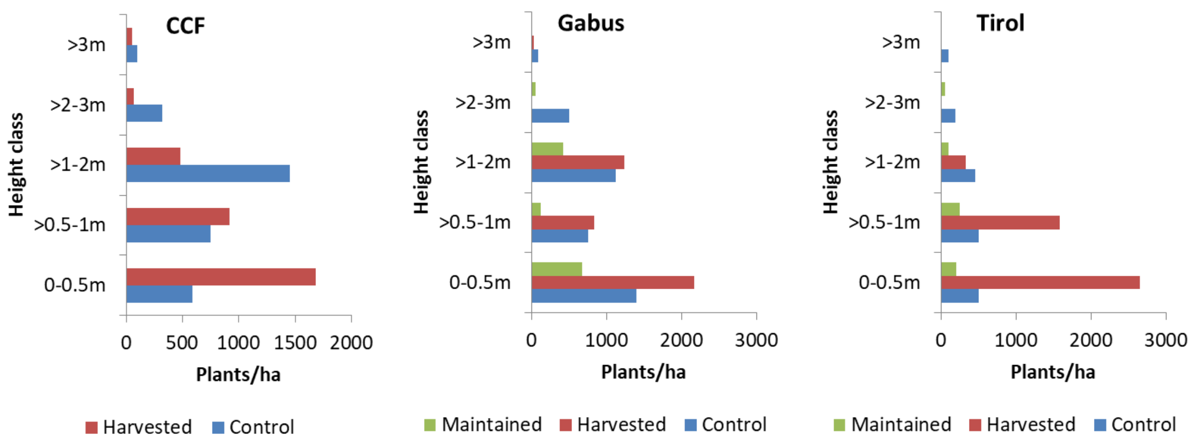


Figure 3 Comparison of treatments in the various study units in terms of the density of woody plants in different height classes.

Plant species diversity, dominance and evenness responses to biomass harvesting

Plant species richness differed between treatments (GLM, $F_{2,18}$=10.1991, P<0.01). Plant species richness was highest in the harvested plots (16.3 species/plot) followed by the control plots (14.8 species/plot), although these did not differ significantly from each other (Figure 4). The species richness in the maintained plots, however, were the lowest (8.3 species/plot, Tukey, P<0.05). In harvested plots, no correlation between species richness and time since harvest were found (P>0.10).

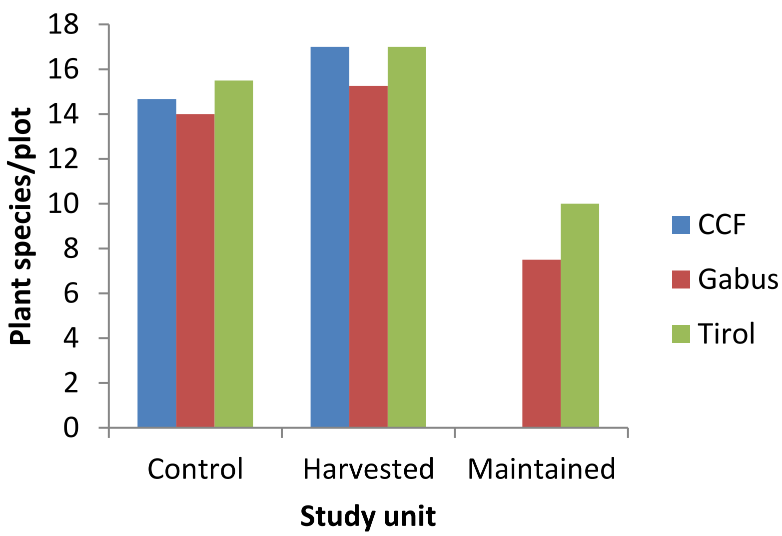


Figure 4 A comparison of plant species richness between and treatments. Maintained refers to sites where the woody biomass was harvested and the site then maintained in an open state.

Plant species diversity (Shannon-Wiener index (H')) differed between treatments (GLM, $F_{2,18}$=15.9039, P<0.001). Diversity was the highest in the harvested plots (mean H'=2.2) followed by the control plots (mean H'=2.1), although these treatments did not differ from each other (Tukey, P>0.05)(Figure 5). Maintained plots had a much lower diversity (mean H'=1.2, P<0.05). In harvested plots, no correlation between species diversity and time since harvest were found (P>0.10).

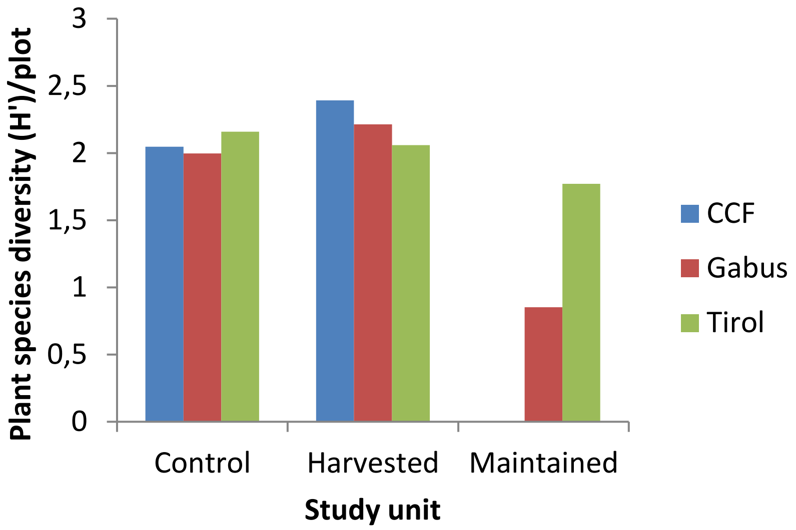


Figure 5 A comparison of plant species diversity (Shanon-Wiener index) between study units and treatments. Maintained refers to sites where woody biomass was harvested and the site then maintained in an open state.

In terms of plant species dominance (Dominance (D) index), treatments differed (GLM, $F_{2,18}$=15.0535, P<0.001). Dominance was the highest in the maintained plots (mean D value=0.47), which differed (Tukey, P <0.05) from the control plots (D=0.18) and harvested plots (D=0.15)(Figure 6). A low dominance value is desirable from a biodiversity perspective. The maintained plots were dominated by grass species including *Eragrostis echinochloidea*, *Aristida stipitata* and *Melinis repens*. In harvested plots, no correlation between species dominance and time since harvest were found (P>0.10).

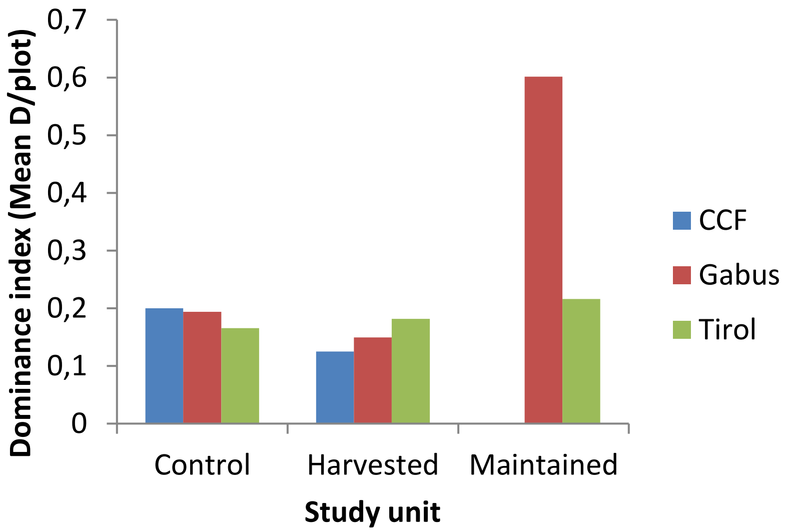


Figure 6 A comparison of plant species dominance (Dominance index) between study units and treatments. Maintained refer to sites where the biomass was harvested and the site then maintained in an open state.

Plant species evenness, how even species are distributed in terms of numbers, did not differ between treatments (GLM, $F_{2,18}$=1.4974, P>0.05). There was a tendency for plant species evenness to increase since time of harvest (Pearson's, r=.58, n=10, P=0.08) in the harvested plots.

Mammal responses to biomass harvesting

The total density of large mammal dung piles did not differ between treatments (GLM, P>0.05), but did differ between study units (GLM, $F_{2,18}$=35.096, P<0.001). The farm Gabus had the highest (Tukey, P<0.05) dung pile density (18.3 piles/plot), compared to Tirol (6.3) and the CCF (2.8 piles/plot). The difference was mainly attributed to higher dung densities of large and medium sized antelope species such as eland, oryx, kudu, red hartebeest, impala and springbuck, which frequent the game fenced Gabus farm.

If the large herbivore dung piles were grouped according to feeding guild (grazer, browser, mixed feeder) differences between treatments emerged for grazers (GLM, $F_{2,18}$=6.825, P<0.01) and browsers (GLM, $F_{2,18}$=5.228, P<0.05), but not for the mixed feeder guild (P>0.05)(Figure 7).

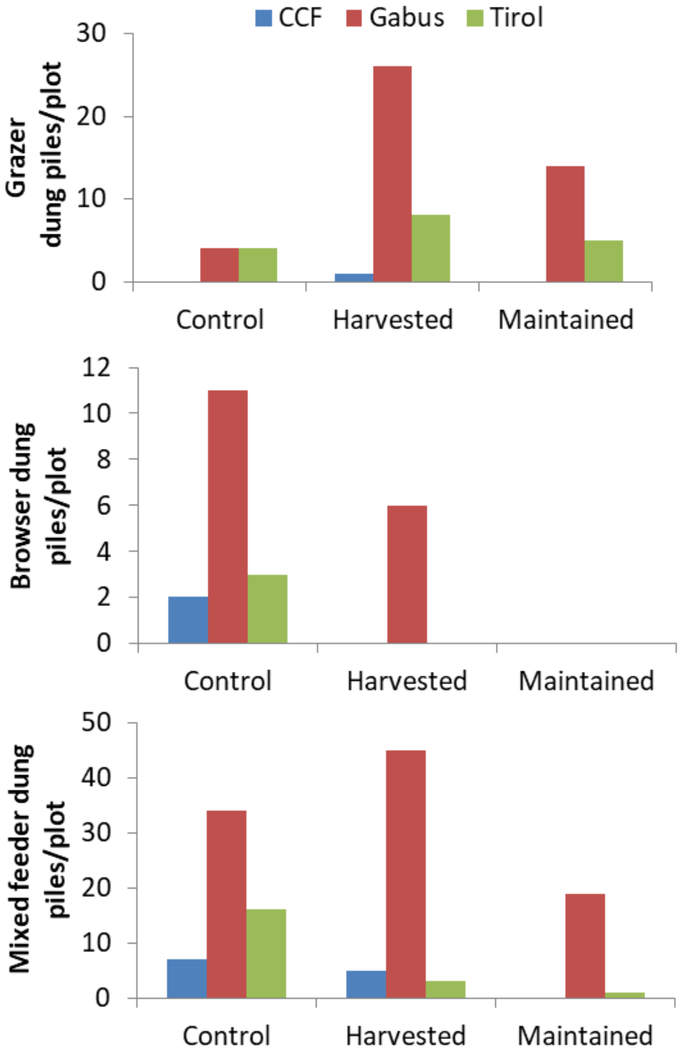


Figure 7 Comparison of dung pile densities between treatments per study units for grazers (top), browsers (middle) and mixed feeders (bottom).

Grazer dung pile density was highest in the maintained and harvested and lowest in the control areas, while browsers followed the opposite trend and was highest in the control areas and lower in the harvested and maintained areas. The dung pile density of mixed feeders did not differ between treatments (P>0.05)(Figure 7).

Neither the burrow density of aardvark nor small mammals differed between treatments or study units (GLM, P>0.05).

Conclusions

Concluding, the study contributed to the understanding of how bush encroached savanna systems respond to woody plant harvesting within a Namibian context. In harvested areas herbaceous productivity and plant biodiversity increased and plant species dominance decreased in harvested areas compared to controls. These are all associated with improvements relative to the bush encroachment state. Continued control of woody plants in harvested areas (maintained in an open state) showed mixed responses. In maintained study plots herbaceous biomass increased but plant species diversity decreased and dominance of selected species increased, which are undesirable traits, probably because these areas were often “over cleared” in terms of current guidelines (Pallet & Tarr 2017). Of great importance is the finding that woody plant density in the seedling-sapling size class showed an increase in harvested areas. If no aftercare takes place, re-encroachment is likely to take place in these areas over time. Clearly *how* aftercare maintenance of woody plants is performed is of great importance. The aim should be to control woody recruitment, but to prevent dominance of single species or height strata in the woody structure.

Wild large herbivores showed a functional response where browsers showed a preference for bush encroached areas and grazers preferred the harvested and cleared areas.

A short-coming of the study was that beta-diversity, the diversity at a larger scale spanning all different treatments, was not determined. The hypothesis is that a combination of open, harvested areas with patches of dense, bush encroached areas will strike a balance between gained productivity and functional biodiversity.

Acknowledgements

We thank the owners and managers of Gabus, Tirol and the CCF for the opportunity to work on their properties and for the information provided. We sincerely thank Titus Shuuya, Elize Nghalipo and Oliver Freyer for collecting the field data.

References

Catana, A.J. Jr. 1963. The Wandering Quarter Method of Estimating Population Density. Ecology, 44, 349-360.

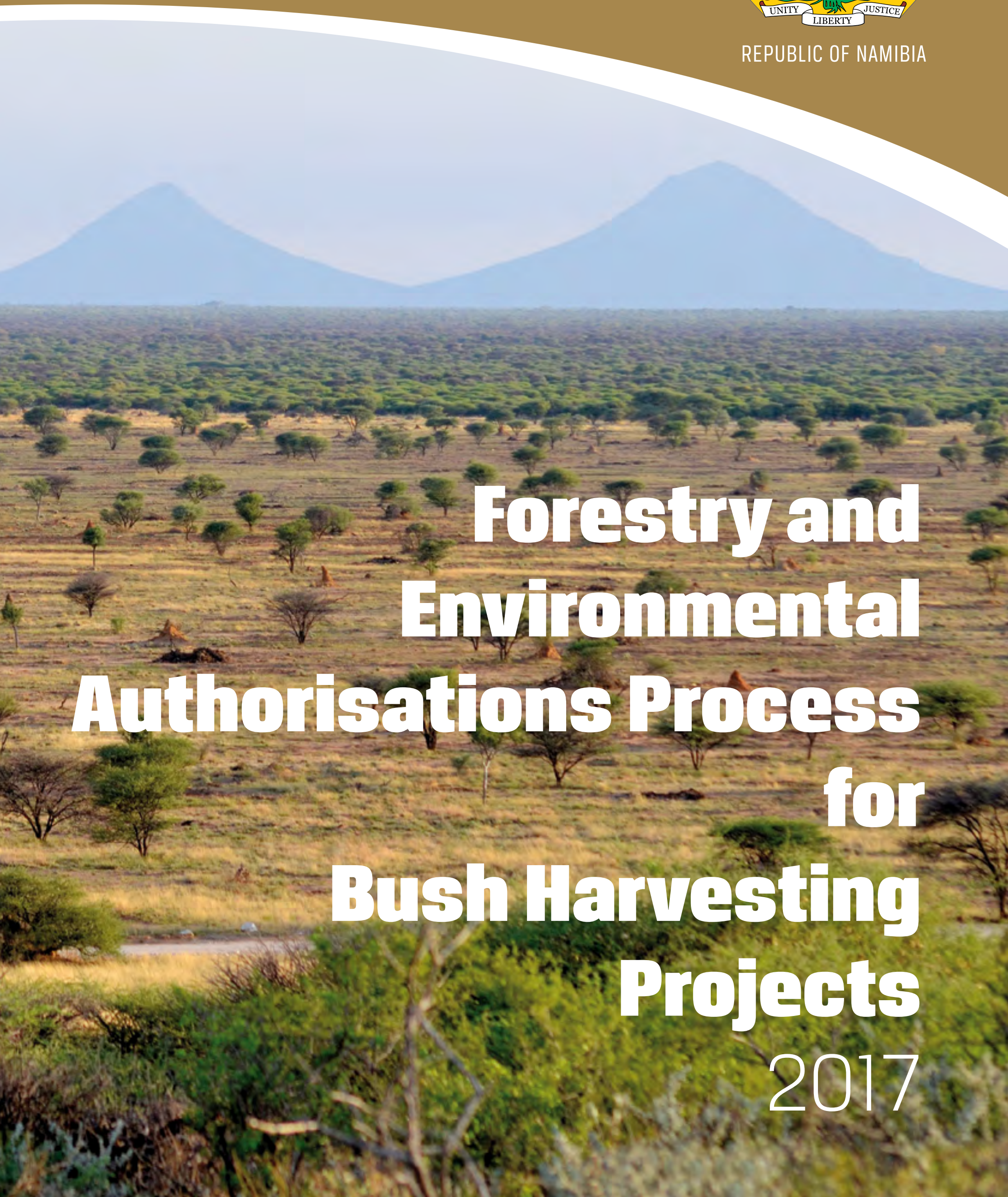
Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2008). PAST-palaeontological statistics, ver. 1.89. Paleontological Museum, University of Oslo, Noruega.(También disponible en línea: http://folk. uio. no/ohammer/past/index. html).

Haydock, K. P., and N. H. Shaw, 1975: The compar- ative yield method for estimating dry matter yield of pasture. Aust. J. Exp. Agric. Anim. Husbandry 15, 663—670.

Pallet, J., Tarr, P., 2017. Forestry and Environmental Authorisations Process for Bush Harvesting Projects. Guidelines for complying with regulations governing bush thinning and value addition projects. Ministry of Agriculture, Water and Ministry of Environment and Tourism.

Ministry of Agriculture, Water and Forestry
and Ministry of Environment and Tourism

REPUBLIC OF NAMIBIA



Forestry and Environmental Authorisations Process for Bush Harvesting Projects

2017


LIEBHERR

Forestry and environmental authorisations process for bush harvesting projects

Guidelines for complying with regulations governing bush thinning and value addition projects

WHAT IS THIS BOOKLET ABOUT?

This booklet explains the Namibian environmental laws and regulations that must be complied with in bush harvesting and value addition projects.

It is based on the study "Strategic Environmental Assessment of large-scale bush thinning and value-adding activities in Namibia" (2016), compiled by the Southern African Institute for Environmental Assessment (SAIEA) for the MAWF/GIZ Support to De-bushing Project.

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Foreword by the Director of Forestry

Namibia used to be a land of open savannas. Now, more than half of the country is covered by thorny and impenetrable bush, greatly reducing the productivity of our land. As well as decreasing the carrying capacity of rangelands, encroacher bush also has a catastrophic effect on Namibia's water resources, drastically decreasing water inflow into underground reserves. For these reasons, the Government of Namibia has committed itself to combat bush encroachment so that our rangelands can be restored.

At the same time we must not forget that the species that form this thorny problem are indigenous to Namibia. They form part of our savannas, and they are important for the ecological processes that sustain us. For instance, trees help to provide nutrients to the soil, they give shade and shelter for livestock and wild animals, and they help to retain soil moisture which in turn keeps grasses going. For these reasons, it is important that we do not totally eradicate the bush. Rather, the emphasis must be on selectively removing the problem bushes, and retaining those larger individuals that are most useful for the health of the rangelands. We must aim to thin the bush, not to de-bush entirely.

People are realising the economic value of the bush, and harvesting of wood products is on the increase. The opportunity to profit from bush therefore carries with it a risk that there will be irresponsible harvesting.

The Directorate of Forestry, in the Ministry of Agriculture, Water and Forestry, plays an important role in ensuring that bush thinning is done appropriately. Our Forestry officials are responsible for granting permits to cut bush, and for monitoring bush harvesting operations. We want to facilitate the right kind of bush thinning, and prevent the unscrupulous cutting of our most useful and protected trees. We commit to helping to restore our "beloved land of savanna", as proclaimed in our National Anthem.

Joseph Hailwa
Directorate of Forestry, Ministry of Agriculture, Water and Forestry

Foreword by the Environmental Commissioner

As a result of bush encroachment, Namibia has an enormous biomass resource at its disposal. It is estimated at 200 million tonnes! Already, people are at work making use of this wood. Encroacher bush is sold as firewood to local communities, made into charcoal for export, and compressed to briquettes. It is used for carving, to make furniture, floorboards and fencing materials. Bush is being turned into fertiliser and even into animal fodder. Wood chips are being used to produce heat for cement production, and other industries such as abattoirs and breweries are starting to realise the potential of this resource. Namibia could even use the woody biomass for decentralised electricity production. Creative and innovative product ideas are developing across Namibia, turning the problem of encroacher bush into an economic opportunity.

The harvesting of encroacher bush will have to be up-scaled drastically to fulfil these hopes. This carries some risk for the natural environment, and it is the responsibility of the Ministry of Environment and Tourism to ensure that ecological damage is avoided. We are here to prevent over-exploitation and environmentally harmful practices, so that our resources are sustained for the benefit of future generations. We should be mindful that these bushes serve as refuge for a number of wildlife habitats.

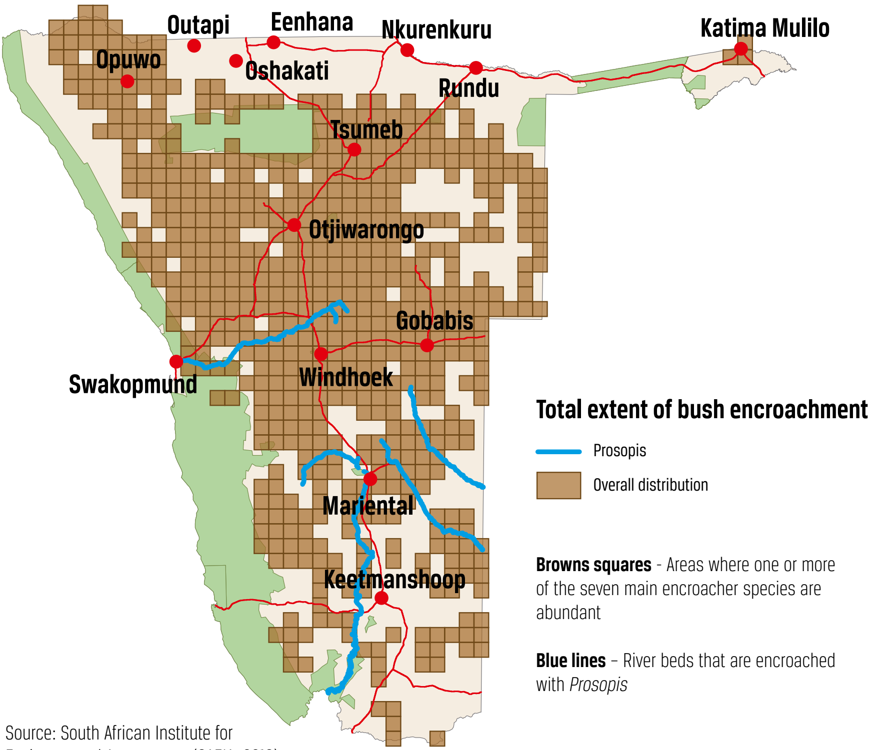
We trust that investors and project developers will recognise the necessity for monitoring and control of bush harvesting operations. To ensure responsible and sustainable bush thinning, the Ministry of Environment and Tourism through the Department of Environmental Affairs will facilitate the authorisation process for bush-harvesting projects by issuance of environmental clearance certificate. Thus, large scale (more than 150 hectares) bush thinning will require an environmental clearance certificate as per the Environmental Management Act No.7 of 2007.

MINISTRY OF ENVIRONMENT AND TOURISM
P/Bag 13306
Windhoek, Namibia
2016 -09- 28
Office of the Environmental Commissioner

Teofilus Nghitila
Department of Environmental Affairs, Ministry of Environment and Tourism

Extent of bush encroachment in Namibia

Bush encroachment remains a major agricultural problem in Namibia, covering about 45 million hectares of the country's savannas, and reducing livestock productivity significantly. The map below is based on the distribution of the main encroacher species, and information on where they have shown dramatic increases in density over the past ±60 years. According to this map, approximately 55% of Namibia is bush encroached.



Source: South African Institute for Environmental Assessment (SAEIA, 2016)

Economics of bush encroachment

An economics study of bush encroachment* states that a programme of bush thinning in Namibia could generate an estimated net benefit of N$48.0 billion (2015 prices) over 25 years, when compared with a scenario of no bush thinning. Bush thinning would generate benefits from livestock production, groundwater recharge, production of firewood and charcoal, and generation of electricity, as well as carbon offsets for electricity. The study estimates that the total benefits from ecosystem services would be about N$76 billion, while the total costs would be about N$28 billion. This results in an estimated net benefit of N$48 billion.

* Namibia Nature Foundation. 2016. An assessment of the economics of land degradation related to bush encroachment in Namibia. A report based on the Economics of Land Degradation (ELD) methodology commissioned by the MAWF/GIZ Support to De-bushing Project.

Obviously, such figures are based on various assumptions which affect the final estimates. Under various scenarios which differ in terms of the quantity of bush that is harvested, the amount of groundwater recharge that is restored, and how rapidly the investments depreciate, the net benefit could range from N$25 billion to N$112 billion. Therefore even under conservative estimates, the economic impact would be significantly positive, and could make a considerable contribution to Namibia's welfare. There are also many unquantified ecosystem services which would be positively affected by bush thinning, which are not included in the dollar estimates provided.

The extensive network of roots of an *Acacia mellifera* explains how bush encroachment can dominate groundwater resources, to the extent that groundwater availability in encroached areas is significantly reduced. One of the main benefits to rangelands from thinning bush is the recovery of groundwater recharge.

Policy framework

The Namibian Constitution

Article 95(1) of the Namibian Constitution commits the state to actively promote and maintain the welfare of the people by adopting policies aimed at the "… maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilisation of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future…"

Vision 2030

Vision 2030 recognises that bush encroachment reduces land productivity, and notes that bush encroachment is complex and expensive to reverse. Overall, as a component of land degradation, it is one of the causes of economic loss, declining food security, and escalating poverty. This leads to human migration, urbanisation and an increased need for the government to import food.

National Agriculture Policy (2015)

This Policy recognises the problems of bush encroachment, desertification and environmental degradation caused by the destruction of forest cover, soil erosion, overgrazing and bush encroachment. The policy defines the aim to "establish mechanisms to support farmers in combating bush encroachment effectively over the short and long term".

National Rangeland Management Policy and Strategy (2012)

The Rangeland Policy and Strategy, adopted by Cabinet in 2012, aims to enable farmers to manage their rangeland resources in such a way that –

- animal production per hectare is sustainably improved
- vulnerability of users to a highly variable resource base is decreased, and
- biodiversity is improved and maintained, so that it is able to continue to provide essential ecosystem services.

For these ends it advises that emphasis should be placed on:

- Improving the nutrient cycle through the promotion of plant diversity, healthy soil structure and functioning ecosystems,
- Improving the water cycle through the promotion of good soil cover and aeration; the creation of sufficient soil organic matter; reducing competition for soil moisture between undesirable bushes and preferred grasses (bush thinning); and restoring eroded land responsible for rapid runoff during high rainfall events, and
- Improving and maintaining the biodiversity of rangelands through: encouraging the correct intensity of plant utilisation; adequate recovery of utilised plants (frequency of utilisation); the reclamation of denuded rangelands; erosion control; the use of biodiversity-friendly parasite control; and managing rangelands for heterogeneity rather than for homogeneity.

The overriding theme in Namibia's policy framework is sustainable use of Namibia's rangelands and combating bush encroachment for their restoration and a recovery of livestock productivity.

Legal requirements: Forestry Permits

Forest Act (2001) and Regulations (2015)

All harvesting of trees and wood, anywhere in Namibia, is governed by the Forest Act and its Regulations. The Act also governs activities which take place in classified forests, namely State Forests, Forestry Management Areas and Community Forests as well as non-classified forest areas. This Act is administered by the Directorate of Forestry (DoF) in the Ministry of Agriculture, Water and Forestry (MAWF).

Harvesting Permits

A Harvesting Permit is required for any tree cutting and/or harvesting of wood in an area greater than 15 hectares per annum as stated under Section 22 (1), 23 (1), 24 (2&3) and 33 (1&2) of the Forest Act (Act 12 of 2001). The permit is issued by a Licensing officer, and stipulates conditions of the harvesting on the reverse side of the permit. Inspection of an area to be harvested is done before the permit is issued, and when an application for renewal is made every 3 months.*

* The period of validity is periodically reviewed by Directorate of Forestry.

Transport Permits

A Transport Permit is required to convey any wood or wood products (e.g. droppers, planks, charcoal, and firewood). It is obtainable from any Forestry Office, and is valid for 7 days.

Export Permits

An Export Permit is required to send any wood or wood products outside Namibia. It is obtainable from any Forestry Office, and is valid for 7 days.

Marketing Permits

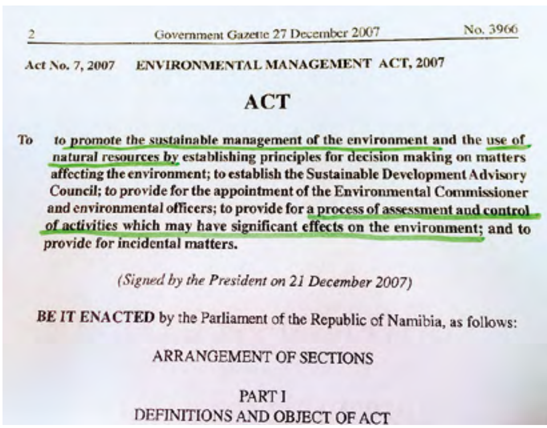
A Marketing permit is required to enable the producer to sell his/her products to any other party. The permit is valid for 3 months in commercial areas while in communal areas the permit is valid for 1 month only.

Legal requirements: Environmental Clearance Certificate

Environmental Management Act (2007) and Regulations (2012)

Under the Environmental Management Act, forestry activities which require authorisation under the Forest Act, may require an Environmental Clearance Certificate. As stipulated in these guidelines, all wood harvesting activities in an area greater than 150 hectares per annum must comply with the Environmental Management Act. This act is administered by the Environmental Commissioner in the Department of Environmental Affairs (DEA) in the Ministry of Environment and Tourism (MET).

Normally, to get Environmental Clearance, an Environmental Impact Assessment (EIA) has to be completed, together with an Environmental Management Plan (EMP). An EIA is an assessment of the environmental damage that a project might cause, and the EMP provides advice on how the negative impacts can be avoided or reduced. An EIA is usually carried out by an independent environmental practitioner. The EIA report is evaluated by the DEA, and if the Environmental Commissioner is satisfied that the negative impacts are minimised, an Environmental Clearance Certificate is issued. The certificate requires the project proponent to diligently implement the EMP.


2 Government Gazette 27 December 2007 No. 3966

Act No. 7, 2007 ENVIRONMENTAL MANAGEMENT ACT, 2007

ACT

To to promote the sustainable management of the environment and the use of natural resources by establishing principles for decision making on matters affecting the environment; to establish the Sustainable Development Advisory Council; to provide for the appointment of the Environmental Commissioner and environmental officers; to provide for a process of assessment and control of activities which may have significant effects on the environment; and to provide for incidental matters.

(Signed by the President on 21 December 2007)

BE IT ENACTED by the Parliament of the Republic of Namibia, as follows:

ARRANGEMENT OF SECTIONS

PART I
DEFINITIONS AND OBJECT OF ACT

This can all be a lengthy and expensive process, and it can bring delays to implementing a project.

For bush harvesting projects, this process has been simplified to avoid the heavy costs and time delays that would hinder bush thinning (see overleaf).

Categories of projects requiring Environmental Clearance

The level of detail for the Environmental Clearance is divided into three categories:

1. Environmental Clearance not necessary

Small bush harvesting operations, covering an area less than 15 ha, requires a harvesting permit to be issued by the District Forestry Office. Areas above 15 ha requires an approval by the Director of Forestry as indicated in Section 23 (1) of the Forest Act.

2. Environmental Clearance based on Generic EMP

Medium-sized bush harvesting operations, covering an area between 150–5,000 hectares, need to obtain Environmental Clearance from DEA. The area to be thinned should be less than 5,000 ha altogether, in one vicinity. The environmental assessment for this Clearance can be customised from the generic Environmental Management Plan provided in this booklet. The level of consultations with interested and affected parties (I&APs) for this category should focus on the neighbouring farms. This is under the assumption that the potential impact is foreseen to be localised. The consent should be submitted to DEA with the application for Environmental Clearance.

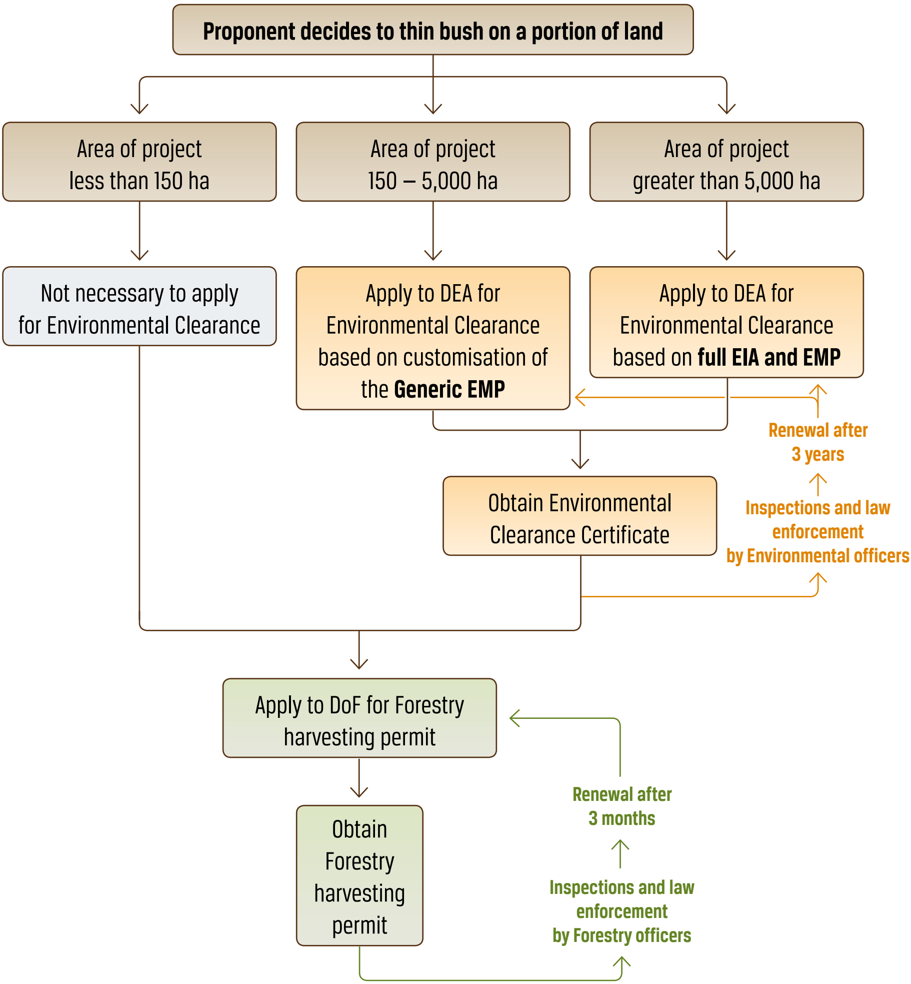
If a farmer harvests individual areas that are less than 5,000 ha, but they contribute to a larger project that covers an area greater than 5,000 ha, then the activities fall into category 3 (full EIA).

3. Environmental Clearance based on dedicated EIA and EMP

Large bush harvesting operations, covering an area greater than 5,000 hectares, need to obtain Environmental Clearance from DEA. These operations are likely to have extensive, complex and/or long-term environmental impacts. They require a full EIA and include a thorough EMP. The EIA must cover all the specific details of the source areas, and individual farms that contribute harvested wood to a large project will all be bound by the conditions described in the EMP.

Violations of the Environmental Management Act are punishable by law.

Combining Forestry and Environmental Clearance authorisations



Customisation of the Generic EMP – Project particulars

The following details must be provided by the project initiator to describe the project and the environment where it will be carried out.

A. LOCATION AND ENVIRONMENT

1. Name of farm(s) / land where project is located. If known, GPS coordinates should also be provided.
2. Legal status of the land.
3. Description of current use of the land, including livestock numbers, water points, camps etc.
4. Name and contact details of farmer / land custodian / manager.
5. Name and contact details of immediate neighbouring farmers / land custodians / managers.
6. Description of the general ecology of the land (e.g. topography, soil type, flora, fauna,...).
7. Description of the bush encroachment problem on the land:
   - 7.1 Tree species causing problems
   - 7.2 At least 3 density estimates for the area to be thinned. (These should be samples that represent the overall problem, and preferably the same places depicted in photos [see page 25–27]).
8. Description of past efforts to manage the bush encroachment problem on the land.

B. DESCRIPTION OF THE PROPOSED BUSH THINNING PROJECT

9. Size of area to be thinned.
10. Expected duration of the project (years).
11. Species to be thinned.
12. Approximate density of trees to remain after thinning (see page 24).
13. Methods of bush thinning to be used.
14. Equipment / machinery / chemicals to be used.
15. Number of staff to be employed.
16. How staff will be recruited.
17. Where staff will live.
18. What contractual arrangements will be made with staff.

Monitoring and control of wood harvesting operations falls under the jurisdiction of the Ministry of Agriculture, Water and Forestry, and the Ministry of Environment and Tourism.

C. DESCRIPTION OF THE BUSH VALUE-ADDING PROJECT

19. Expected duration of the project.
20. Products to be produced (description, quantity).
21. Size of area where value addition project will be located.
22. Methods of production to be used.
23. Equipment to be used.
24. What liquid or solid waste will be generated (type and quantity).
25. Where the waste will be disposed.
26. Where the water will come from.
27. How much water will be used.
28. What air emissions will be generated.
29. How the product will be taken to market.
30. Who and where the off-taker/market is.
31. Number of staff to be employed.
32. How staff will be recruited.
33. Where staff will live.
34. What contractual arrangements will be made with the staff.

D. ADDITIONAL INFORMATION

35. Farm map (can be Google Earth image showing farm boundaries).
36. Photos of bush encroached areas (corresponding with the places where tree density estimates were made, see point 7.2).
37. Any other information that further describes the project.

Generic Environmental Management Plan (EMP)

The Generic EMP deals with most of the impacts that need to be managed, irrespective of where the project is located. However, no two farms or projects are identical, so this Generic EMP **must be customised for each and every project**. The proponent must study the generic EMP, delete those actions that are not relevant to his/her project/site, modify those actions that need fine-tuning, or even add new actions that are relevant. It is not acceptable to just submit this Generic EMP as it stands.

This EMP considers a range of issues, clustered under suitable headings for ease of reference. The issues are not listed in order of priority – they are all important.

1. AVOID DAMAGE TO PROTECTED AND LARGE TREES, AND TO RANGELANDS

Impact description	Mitigation measures	Indicators
Loss of protected tree species	• Avoid cutting protected trees (Annex 2, page 28). Many of the protected species are frequently found amongst dense encroacher bush, so they are at risk of being destroyed by bush management practices e.g. harvesting machines, arboricides, and even hand labour, if not adequately supervised. • Protected trees must be marked (e.g. with hazard tape) and all staff must know that marked trees are out of bounds. • All staff must be informed in writing about the consequences of breaking this rule, and it must be clear that the rule is understood.	• No Protected trees are cut, unless permitted in the Harvesting Permit.
Loss of large trees	• All trees taller than 4 m, or greater than 18 cm diameter at the base, must be retained. Large dead trees should also not be cut. The only exception is if the vegetation consists entirely of encroachers that are all over 4 m. In that case, follow the formula for desired density after thinning (Annex 1).	
Ecological imbalance due to over-harvesting	• All bush thinning should aim to leave a heterogeneous mix of trees and bush. The veld that remains should have a variety of tree species (including some of the encroacher species), of different size classes, and spaced so that there are some open patches and some dense patches, to provide a variety of habitats for animals. • The desired density after thinning depends on the encroacher species, the soil and the average rainfall. Annex 1 describes the approximate density to aim for.	• Correct level of harvesting, adequate numbers of trees and islands remain.

Impact description	Mitigation measures	Indicators
Disturbance of sensitive plant habitats	With the exception of *Prosopis* and *Black wattle*, there must be no bush/ tree cutting in sensitive habitats including: • All plant communities within 100 m of a fountain or spring or river bed. • *Acacia erioloba – Tylosema esculentum* habitats, and all stands of *Acacia erioloba* trees. • *Kirkia acuminata – Danthoniopsis dinteri* woodlands in the Otavi Mountains. • *Spirostachys africana* thickets/woodlands. • *Olea europea subsp. africana – Euclea undulata* thickets. • *Terminalia sericea – Acacia fleckii* thickets occurring on remnants of sand dunes within the karstveld. • *Palmveld (Hyphaene petersiana).*	• No tree / bush cutting in such areas, with the exception of *Prosopis* and *Black wattles.*

2. AVOID DISTURBANCE TO WILDLIFE AND LIVESTOCK

Impact description	Mitigation measures	Indicators
Loss of livestock and wildlife from poaching	• Killing of livestock or wildlife, and setting of snares, is prohibited. Anyone caught involved in such activities should be fired immediately. • Possession of a firearm or snare is prohibited. Such items should be confiscated if detected, and the offender issued with a warning. • All staff must be informed in writing about the consequences of breaking these rules, and it must be clear that the rules are understood.	• No snares or firearms on site. • No incidences of poaching.
Escape of livestock or wildlife due to damaged fences and/or gates left open	• Fences may not be damaged. • Gates should always be left the way you find them.	• No livestock or wildlife escape from the property due to damaged fences or gates left open by project staff.
Disturbance of sensitive animals and birds	• Nests of large raptors (e.g. eagles, vultures) must be avoided by at least 100 m. If such nests are found, the clump of vegetation around them should not be harvested. • Some reptiles such as tortoises and pythons move very slowly. Staff, especially machine drivers, should look out for any such animals and avoid causing harm to them.	• No raptors disturbed or nests abandoned. • No reptiles or other animals killed by harvesting operations.

3. AVOID SOIL EROSION AND LOSS OF SOIL FERTILITY

Impact description	Mitigation measures	Indicators
Loss of topsoil as a result of bush thinning	• No bush cutting permitted on slopes steeper than 12.5% (i.e. 1-in-8). • Bush cutting is also not recommended on slopes of 5 – 12.5% (i.e. between 1-in-20 and 1-in-8). • Machinery should always move approximately along the contours, not directly up and down slopes. • If slopes are significantly bush encroached it is recommended that they be set aside as part of the area that is not harvested.	• No bush cutting on steep slopes. • No gullies or erosion caused from bush harvesting machinery or tracks made for the machines.
Erosion or destabilisation of river banks as a result of bush thinning	• No bush cutting permitted within 100 m of a watercourse, pan or spring. • Two exceptions are permitted: – Where bush has encroached into seasonal pans, one may clear the floor of the pan but not around the outside margins. – Prosopis and black wattle may be removed from within a watercourse and from river banks.	• No trees cut in riverbeds or within 100 m of the banks.
Loss of soil fertility	• Bush encroachment on sandy soil should be thinned less vigorously than on non-sandy soils, as the trees are responsible for most of the soil fertility. All sites where *Terminalia sericea* and *Acacia fleckii* are dominant should be harvested according to the formula TE* per hectare = 3 × annual rainfall.	• Correct level of harvesting, adequate numbers of trees remain.

*TE = Tree equivalent is a woody tree or bush of 1,5 m (3 m tree represents 2 TEs, 0,75 m tree represents 0,5 TEs)

4. PREVENT POLLUTION OF WATER SOURCES

Impact description	Mitigation measures	Indicators
Pollution of soil and water from waste products (e.g. tars, ash, brine) generated in bush-to-energy plants or factories for wood products	• Where appropriate, the waste should be re-used. E.g. i) ash should be re-distributed in the harvested areas, so that nutrients are returned to the soil; ii) Some of the tars produced in a wood gasifier might be re-usable as fuel in the plant. • Where re-use is not possible, appropriate disposal must be considered e.g. in a site equipped for hazardous waste disposal, with measures to prevent seepage into the soil and groundwater. • Brine and contaminated water should be collected and stored in sealed evaporation ponds. The residue should be regularly scraped up and disposed of in an appropriate site.	• Composition of effluents should be specified by the proponent. Sporadic sampling of local water and soil should test for contaminants. • Water quality inspectors from MAWF and/or MoH need to exercise control over disposal of effluents.
Small-scale, local pollution patches (e.g. fuels, oils, greases) caused by spillages and servicing of machinery	• Regular maintenance and servicing of vehicles and machinery, to prevent breakdowns and the need for on-site repairs.	• Sporadic sampling of local water and soil should test for contaminants.

5. PREVENT AIR POLLUTION

Impact description	Mitigation measures	Indicators
Smoke given off from charcoal kilns can, under certain conditions, accumulate to harmful levels	• Training and supervision of charcoal producers can improve the efficiency of the process, so that less smoke is produced. • Retort kilns, operated efficiently, produce almost no smoke.	• No complaints about air emissions from neighbours / local people.
Wood factories may generate smoke, soot and other air pollutants	• Air emission control measures e.g. scrubbers installed in chimneys.	• No complaints about air emissions from neighbours / local people.

Smoke from charcoal kilns is generally quickly dispersed and makes relatively little impact. But under certain conditions – cold nights, in hilly terrain – the smoke can collect in valleys and cause considerable nuisance.

6. PREVENT REGROWTH THROUGH AFTER-CARE

Impact description	Mitigation measures	Indicators
The original encroacher species, or more aggressive colonisers, will establish themselves in the thinned-out areas	Preventing bush regrowth following harvesting can be achieved through: • Hand application of arboricides, • Mechanical removal of problematic single plants, • Stem burning, • Judicious use of fire, • Intensive browsing by goats or antelope, especially when regrowing plants are still small.	• Thinned areas remain at the required tree density.
After-care burning and/or stem burning generates air pollution (e.g. smoke, soot) and fires may run away, threatening other rangeland and neighbours	• No burning when the day temperature exceeds 25 °C and/or the wind exceeds 20 kph during the months of April to July. • Notify neighbours a day or two before the controlled burning. • Remove livestock from the area prior to burning. • Ensure there are escape routes for larger forms of wildlife so that they do not succumb to the fire. • Avoid burning in areas where there are active nests of endangered bird species (e.g. vultures, eagles). • Fire-fighting equipment (fire-cart, rubber beaters and/or backpack spray) must be accessible and in working condition. • Prepare firebreaks that are at least 15 metres wide, prior to the controlled burn, or define an area bordered by roads which are wide enough to prevent a fire 'jumping'. • Monitor the area after the burn is over, in case a smouldering coal or dung is blown into an unburnt area.	• Fires are "fit for purpose" and contained as planned.

7. FOLLOW HEALTH AND SAFETY PRECAUTIONS

Impact description	Mitigation measures	Indicators
HIV/AIDS infection due to risky sexual behaviour	• Provide HIV/AIDS awareness information to workers. • Provide free condoms. • Provide recreation facilities (games/TV etc.).	• Evidence of training events. • Facilities are accessible.
Bites / stings from snakes, scorpions, insects	• Staff may not catch or kill snakes or scorpions. • Staff must wear protective glasses, gloves, closed shoes, hard hat and overalls while working. • A First Aid kit, which includes an aspivenom pump, must be accessible for all staff. • Accommodation / eating areas should be kept clean at all times, garbage placed in closed containers to avoid attracting vermin, insects. • All staff must be informed in writing about the consequences of breaking these rules, and it must be clear that the rules are understood.	• Written instructions regarding handling of animals. • Protective gear being worn. • Evidence of First Aid training events. • First Aid kits accessible.

Impact description	Mitigation measures	Indicators
Injuries to face, eyes, skin and other parts, from thorns, dust, etc.	• Staff must wear protective gear while working.	• Protective gear being worn.
Loss of life / injury from traffic accidents	• Vehicles roadworthy and properly maintained. • Drivers comply with all road safety regulations, including avoiding overloading and speeding, and wearing safety belts. • Vehicles travel with lights on whether using tar or gravel roads. • No driving at night. • Instruction in road safety must be given and repeated periodically amongst all drivers. • All staff must be informed in writing about the consequences of breaking these rules, and it must be clear that the rules are understood.	• Vehicles roadworthy. • Zero traffic fines and accidents. • Evidence of drivers receiving instruction and/or training in road safety. • All drivers licenced.
Loss of life / injury from machinery accidents	• Machines properly maintained. • Operators know and comply with machine instruction manuals. • Instruction in machine operating safety must be given periodically to operators.	• Machine service records available. • Zero machine-related accidents. • Evidence of drivers receiving instruction and/or training in road safety.
Loss of life / injury from fire accidents	• Fire-fighting equipment (rubber beaters and/or backpack spray) must be accessible at key points during controlled burning. • If a fire starts, notify the farm owner/ manager immediately. Deploy beaters/backpack sprayers immediately. • A fire cart must be available at each work station with water supply and pumps to deal with fire. • Regular training for site staff on fire prevention and control, especially in the dry season. • Open fires only permitted in a designated facility at the site camp. Campfire must be extinguished when staff go to bed, or leave the camp. • No cigarette butts, matches or any other burning object may be thrown into the veld. • An area of at least 3 metres must be cleared of grass around active charcoal kilns. • Combustible refuse must be burnt in a drum. An area of 3 metres must be cleared of grass around such a drum. The drum may not be left unattended until the fire is extinguished and a lid has been placed on the drum. • All staff must be informed in writing about the consequences of breaking these rules, and it must be clear that the rules are understood.	• No fire incidents. • Evidence of a fire-fighting training events. Written instructions regarding fire prevention accessible. • Fire-fighting equipment available at base camp, on vehicles and at charcoal kilns. • Suitable drum available for combustible refuse, and located in cleared area. • Suitable cleared area designated for campfire at base camp.

Best practice / Poor practice in bush harvesting

Poor practice:
Unselective and excessive bush clearing

Severe disturbance of the soil, and almost complete clearing of the bush, will result in aggressive regrowth, producing worse bush encroachment than before.

Too much bush has been cleared.

Patches of cleared bush in the Otavi Mountainland. The camps that have been cleared have almost no trees at all. This is undesirable as scattered trees improve the quality of the rangelands.

Good practice:

Examples of selective bush thinning, leaving some trees as prescribed by the TE formula

Poor practice:
Aerial spraying of arboricides

Aerial spraying of arboricides is prohibited under the Forest Act. Aerial application is also condemned for ecological reasons, as it does not thin the bush selectively. Note that all the trees in this landscape have been killed, except for a few broad-leafed species which are not affected by the chemical.
Arboricide pellets are also not advised, as they can get washed along the surface by rain, and end up killing non-target trees.

Good practice:
Foliar (leaf spray) and stem-applied arboricides

Foliar (leaf spray) and stem-applied arboricides are recommended. They can be applied directly to selected trees.

Good practice:
Not clearing bush along the margins of rivers (unless the trees are *Prosopis*)

Bush is naturally denser along the margins of rivers. The trees are usually taller, providing important habitat for birds and animals. This bush should not be cleared, unless the trees are *Prosopis*.
This is the Swakop River in the area north-east of Okahandja. The rangelands appear to be in good condition, with little bush encroachment.

Annex 1

Recommended density of trees after bush thinning

This annex defines what level of bush thinning is most appropriate, to achieve the goal of ecological restoration of rangelands. The information is categorised according to the main encroacher species. It uses a formula based on 'tree equivalents' (TEs) and average annual rainfall. A TE is defined as a woody tree or bush of 1,5 metres height. Therefore a 3 m tree represents 2 TEs. A 0,75 m tree/bush represents 0,5 TEs.

Main principles for bush thinning

- All bush thinning should aim to leave a heterogeneous mix of trees and bush. The veld that remains should have a variety of tree species (including some of the encroacher species), of different size classes, and spaced so that there are some open patches and some dense patches, to provide a variety of habitats for animals.
- Bush thinning should be carried out in a phased approach so that the system is not shocked by an abrupt change from dense bush to open veld.
- All protected plants as listed in Annex 2 should not be harvested for bush thinning, however, exceptions can be made in cases of high densities. Felling of such plants (e.g. Colophospermum mopane) should be done under strict supervision by Forestry officials.
- If arboricides are going to be used, foliar (leaf spray) and stem-applied arboricides are recommended. Pellets should not be used, as they tend to get washed along the surface by rain, and end up in non-target areas.
- Dry river beds tend to carry more trees, and larger trees. Forestry regulations state that trees should not be killed within 100 m of a river course. Thinning is required in densely encroached river margins, but one should leave a higher density of trees than on the adjacent habitat. It is especially important to leave the large trees and protected species along a river course. The exception to this is *Prosopis*, which invades river beds, and should be eradicated completely.
- Judicious thinning should leave behind a sufficient number of trees (following the formulas provided below) to create a stable savanna that does not need major intervention at short intervals after the initial thinning.
- Training of the work force is necessary before harvesting starts, so that workers know which trees to target and which to avoid. Work teams need to be managed so that any excessive harvesting or killing of the wrong species is noticed and corrected.

DOMINANT ENCROACHER SPECIES

Acacia (mellifera, reficiens, luderitzii, erubescens, fleckii, nebrownii)

- Leave all trees greater than 18 cm diameter (measured at ground level).
- Leave all protected species.
- Leave enough Acacias so that the total density of TEs per hectare = 1.5 times the average rainfall. I.e. in an area with ~400 mm rain, the total density of all trees should be ~600 TEs / ha.
- In sandy substrates, leave enough Acacias so that the total density of TEs per hectare = 2 times the average rainfall. I.e. in an area with ~400 mm rain and sandy soil, the total density of all trees should be ~800 TEs / ha.

DOMINANT ENCROACHER SPECIES

Dichrostachys cinerea

Open veld in Windhoek with a few medium-sized *Dichrostachys* trees and *Combretum apiculatum* trees. Hidden in the grass are small *Dichrostachys* trees that should be thinned out.

- Leave all trees greater than 18 cm diameter (measured at ground level). Any *Dichrostachys* greater than 10 cm diameter (these are the taller individuals) should also be left.
- Leave all protected species.
- Leave enough *Dichrostachys* so that the total density of TEs per hectare = 1.5 times the average rainfall. I.e. in an area with ~400 mm rain, the total density of all trees should be ~600 TEs / ha.
- Protect the soil by packing brush.
- Aftercare is essential to prevent re-infestation.

DOMINANT ENCROACHER SPECIES

Terminalia sericea

- Leave all trees greater than 18 cm diameter (measured at ground level).
- Leave all protected species.
- Leave enough *Terminalias* so that the total density of TEs per hectare = 3 times the average rainfall. I.e. in an area with ~400 mm rain, the total density of all trees should be ~1,200 TEs / ha. This recognises the high importance of the trees in supplying nutrients to the sandy soil.
- Remember that a large *Terminalia sericea*, approximately 6 m high, is 4 TEs.

DOMINANT ENCROACHER SPECIES

*Mopane**

*Mopane is classified as a protected plant, thinning is only exceptional in cases of high densities.

- Leave all trees greater than 18 cm diameter (measured at ground level).
- Leave all protected species.
- Leave enough mopanes so that the total density of TEs per hectare = 2 times the average rainfall. I.e. in an area with ~400 mm rain, the total density of all trees should be ~800 TEs / ha. This recognises the importance of mopanes as fodder.
- All cases where thinning is planned in mopane-dominated veld, especially where the veld is degraded (e.g. lack of grass, soil erosion), the area should first be inspected by Forestry officials or a bush expert, to assess the level of harvesting that should be done. It might be advisable in such conditions to leave more trees than 2 times the annual rainfall as specified above.

DOMINANT ENCROACHER SPECIES

Rhigozum trichotomum

- Leave all other tree and bush species, including all protected species.
- Leave enough *Rhigozum* so that the total density of TEs per hectare = 2 times the average annual rainfall. I.e. in an area with ~200 mm rain, the total density of all trees and bushes should be ~400 TEs / ha.
- Remember that a *Rhigozum* bush is usually ~0.75 m tall, i.e. 0.5 TE. If there are no other trees or bushes, the density of *Rhigozum* should be ~800 bushes / ha.

DOMINANT ENCROACHER SPECIES

Prosopis

Prosopis trees in the Auob River at Gochas. Note that they are not confined to the river; they are also invading areas beyond the river bed.

- Take out all *Prosopis* trees.
- Use only approved methods, such as manual chopping or responsible use of arboricides. Do not use polluting methods such as applying engine oil to stems which have been cut.

Annex 2

List of Protected trees

All the tree species listed below are classified as Protected under the Forest Act (2001) and Regulations (2015).

Species name	English common name	Reasons to be protected (ES = Ecosystem Services)
Acacia erioloba	Camel-thorn	Heavily utilised by humans and animals - medicinal, cash crop, unsustainable harvesting of fuel wood for export, slow growth rate, cultural value, economic value. **ES** - *keystone species*
Acacia nigrescens	Knob-thorn	Used by humans and animals -wood used for construction, utensils, fuel, tanning, browsed by game). **ES** - *retains river banks.*
Acanthosicyos horridus	!Nara	Cultural and economic value. **ES** - *Dune stabiliser.*
Adansonia digitata	Baobab	Heavily utilised by humans and animals. **ES** – *keystone species*
Adenia pechuelii	Harms Elephants-foot	Unsustainable harvesting for horticultural trade, slow growth rate, slow and/or episodic recruitment.
Adenium boehmanium	Bushman poison	Unsustainable harvesting for horticultural trade.
Afzelia quanzensis	Pod mahogany	Extensively used by humans and animals - curios, medicinal, timber, potential as ornamental trees, browsed by animals. Slow growth rate, restricted range.
Albizia anthelmintica	Worm-cure albizia	Utilised by humans and animals - medicinal, utensils, browsed by livestock and game.
Aloe dichotoma	Quiver tree	Unsustainable harvesting for horticultural trade, slow growth rate, cultural value, slow and/or episodic recruitment.
Aloe pillansii	Giant quiver tree	Slow growth rate, restricted range, slow and/or episodic recruitment.
Aloe ramosissima	Maiden's quiver tree	Slow growth rate, restricted range, slow and/or episodic recruitment.
Baikiaea plurijuga	Zambezi teak or Rhodesian teak	Heavily utilised for timber, implements, utensils, wood carvings.
Berchemia discolour	Bird-plum	Heavily utilised by humans and animals.
Boscia albitrunca	Shepherd's tree	Heavily utilised by humans and animals.
Burkea africana	Burkea	Heavily utilised by humans - timber, firewood, implements.
Caesalpinia merxmeullerana	Orange-river caesalpinia	Restricted range.
Citropsis daweana	Wild citrus	Wild crop relative - genetic resource, restricted range.
Colophospermum mopane	Mopane	Heavily utilised by humans and animals (browse and forage) - charcoal, timber, fuel wood, construction, medicine, host to important edible caterpillar; slow growth rate, cultural value.

Species name	English common name	Reasons to be protected (ES = Ecosystem Services)
Combretum imberbe	Leadwood	Heavily utilised by humans and animals - fuel wood, construction material, implements, illegally harvested for charcoal, other purposes, browse, shade; Cultural value, extremely slow growth rate.
Commiphora capensis	Namaqua corkwood	Illegally harvested for horticultural trade, restricted range.
Commiphora cervifolia	Antler-leaved corkwood	Illegally harvested for horticultural trade, restricted range.
Commiphora dinteri	Namib corkwood	Illegally harvested for horticultural trade.
Commiphora gariepensis	Orange River corkwood	Restricted range.
Commiphora giessii	Brown-stemmed corkwood	Restricted range.
Commiphora gracilifrondosa	Karee corkwood	Restricted range, Illegally harvested for horticultural trade.
Commiphora kraeuseliana	Feather-leafed corkwood	Illegally harvested for horticultural trade, restricted range.
Commiphora namaensis	Nama corkwood	Illegally harvested for horticultural trade.
Commiphora oblanceolata	Swakopmund corkwood	Very small, widely scattered populations, restricted range.
Commiphora saxicola	Rock corkwood	Illegally harvested for horticultural trade.
Commiphora virgata	Slender corkwood	Cultural value - host to edible caterpillar.
Commiphora wildii	Oak-leaved corkwood	Cultural value - resin for perfume.
Cyphostemma bainesii	Gouty vine	Illegally harvested for horticultural trade, restricted range.
Cyphostemma currorii	Kobas	Illegally harvested for horticultural trade.
Cyphostemma juttae	Blue kobas	Illegally harvested for horticultural trade, restricted range.
Cyphostemma uter	Kaoko kobas	Restricted range.
Dialium engleranum	Kalahari podberry	Extensively used by humans – fruit an important part of diet of San and Kavango peoples, medicinal, timber, implements.
Diospyros mespiliformis	Jackal-berry	Heavily utilised by humans and animals - important fruit tree, timber, cash crop, utensils, watos, fuel wood, medicinal, fruit eaten by animals and frugivorous birds. Slow growth rate.
Elephantorrhiza rangei	Karas elephant-root	Restricted range and habitat.
Entandrophragma spicatum	Owambo wooden-banana	Cultural value, slow growth rate, restricted range.

Species name	English common name	Reasons to be protected (ES = Ecosystem Services)
Erythrina decora	Namib coral-tree	Small populations scattered over wide area, cultural value, potential horticultural value.
Euclea asperrima	Mountain guarri	Restricted range.
Euclea pseudebenus	Wild ebony	Slow growth rate. **ES** - *keystone species, prevents erosion of water courses.*
Faidherbia albida	Ana tree	Heavily utilised by stock and game, important shade tree in arid west. **ES** - *Important component of riparian fringe, prevents erosion of river beds, keystone species.*
Ficus burkei	Strangler fig	Fruit for humans and animals, restricted range.
Ficus cordata	Namaqua rock-fig	Fruit for humans and animals.
Ficus sycomorus	Sycamore fig	Fruit for humans and animals.
Guibourtia coleosperma	False mopane	Heavily utilised by humans and animals - food, cash crops, very important shade tree, timber, watos, utensils.
Hyphaene petersiana	Makalani palm	Heavily utilised by humans and animals - utensils, basketry, thatching, fuel, ropes, palm wine, food.
Kirkia dewinteri	Kaoko kirkia	Restricted range.
Lannea discolor	Live-long	Used by humans and animals, restricted range.
Maerua schinzii	Ringwood tree	Heavily used by humans and animals, slow growth rate.
Moringa ovalifolia	Phantom tree	Heavily used by humans and animals - horticultural value, browse, tourism.
Neoluederitzia sericeocarpa	Silk-seed bush	Restricted range.
Ozoroa concolor	Green resin-bush	Restricted range, scattered distribution.
Ozoroa namaquensis	Gariep resin-tree	Restricted range.
Pachypodium lealii	Bottle tree	Slow growth rate, unsustainable harvesting for horticulture trade.
Pachypodium namaquanum	Elephant-trunk	Slow growth rate, unsustainable harvesting for horticulture trade, restricted range.
Pappea capensis	Jacket-plum	Utilised by humans and animals - important shade tree, edible fruit, browsed. **ES** - *Keystone species, prevents erosion in rivers.*
Philenoptera violacea	Apple-leaf, rain tree	Important component of riparian and floodplain canopy. Utilised by humans and animals - fences, watos, medicines, browse, fodder.
Protea gaguedi	African white protea	Restricted range, heavily utilised by humans – medicinal overharvesting of roots.
Pterocarpus angolensis	African teak, kiaat	Economic value, heavily utilised for timber, implements, utensils, wood carvings.
Salix mucronata subsp. capensis	Small-leaved willow, river willow	Stabilisation of river banks, shade, heavily utilised by humans – overharvesting for fuel wood, potentially threatened, restricted range.

Species name	English common name	Reasons to be protected (ES = Ecosystem Services)
Schinziophyton rautanenii	Manketti	Heavily utilised by humans and animals - utensils, curios, musical instruments, timber, shade, fruit a very important food and cash crop.
Schotia afra var. angustifolia	Karoo schotia	Utilised by humans for wood, restricted range.
Sclerocarya birrea	Marula	Heavily utilised by humans and animals for fruit, shade, browse, medicines, wood.
Searsia lancea	Karee	**ES** - *prevent erosion of river banks.*
Sesamothamnus benguellensis	Kaoko sesame-bush	Illegally harvested for the horticultural trade, slow growth rate, restricted range.
Sesamothamnus guerichii	Herero sesame-bush	Illegally harvested for the horticultural trade, slow growth rate.
Sesamothamnus leistneri	Large-leaved sesame-bush	Illegally harvested for the horticultural trade, slow growth rate, restricted range.
Spirostachys africana	Tamboti	Heavily utilised by humans – timber.
Sterculia africana	African star-chestnut	Economic value - tourism and horticulture. Utilised by humans – medicinal and food.
Sterculia quinqueloba	Large-leaved sterculia	Economic value - tourism and horticulture, restricted habitat.
Strychnos cocculoides	Corky monkey-orange	Economic value - cash crop. Heavily utilised by humans and animals – fruit.
Strychnos potatorum	Black bitterberry	Utilised by humans - fish poison, shade; and animals (food and shade), restricted range. **ES** - *important component of river and flood plain vegetation.*
Strychnos pungens	Spine-leaved monkey-orange	Economic value - cash crop. Heavily utilised by humans and animals - fruit, medicinal.
Strychnos spinosa	Spiny monkey-orange	Economic value - cash crop. Heavily utilised by humans and animals - fruit and furniture, restricted range.
Tamarix usneoides	Wild tamarisk	Browsed by game. **ES** - *prevents erosion of river beds and river banks, important component of riparian vegetation.*
Tylecodon paniculatus	Southern botterboom	Unsustainable harvesting – horticultural trade, restricted range.
Welwitschia mirabilis	Welwitschia	Cultural value, scientific value, economic value - tourism.
Ziziphus mucronata	Buffalo-thorn	Utilised by humans and animals - medicinal, construction, implements, fuel wood, browsed by livestock and game. **ES** - *prevents erosion of river beds and river banks, important component of riparian vegetation.*

Annex 3

Scientific and common names of key encroacher species

Scientific name	Common names
Acacia erioloba	Camel-thorn, omuthiya, omumbonde, omuonde, //ganab, kameeldoring, kameldornbaum
Acacia erubescens	Yellow-bark acacia, omungongomwi, withaak, berkebos
Acacia fleckii	Sandveld acacia, blade-thorn, mungamba
Acacia hebeclada	Candle-pod acacia, otjimbuku, trassiebos, kerzenakazie, stehschote
Acacia luderitzii	Kalahari acacia
Acacia mellifera	Black-thorn acacia, swarthaak, omusaona
Acacia nebrownii	Water-thorn, /nubib, orupunguya, slapdoring, pfannenstrauch
Acacia reficiens	Red umbrella-thorn, rooihaak, rotrindenakazie
Colophospermum mopane	Mopane, omusati, mupani, mopanie
Dichrostachys cinerea	Sickle-bush, omutjete, sekelbos, papwielbos, farbkätzchenstrauch
Kirkia acuminata	Mountain kirkia, omulemba, omuhoho, bergsering, weisseseringe
Rhigozum trichotomum	Three-thorn rhigozum, //hau.b/s, okatakambindu, driedoring, dreidorn
Spirostachys africana	Tamboti, omuhongo, ohongo, tambotie, tambuti, adlerholz
Terminalia prunoides	Purple-pod terminalia, omuhama, //gaetab, bloedvrugboom, deurmekaarbos, blutfruchtbaum
Terminalia sericea	Silver cluster-leaf, mugaro, omugolo, za'o, geelhout, vaalboom, fahlbaum, gelbholz
Tylosema esculentum	Gemsbok bean, marama bean

Acacia erioloba open savanna north of Rehoboth.

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Design and layout
Martin Markstein, www.dermarkstein.de

Photos
by SAIEA except for:
front cover: © Piet Laubscher-Otjiwa Lodge
Inside front cover:
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First published
September 2016

Last updated
March 2017

REPUBLIC OF NAMIBIA

Ministry of Agriculture, Water and Forestry and
Ministry of Environment and Tourism

Harvesting of encroacher bush is expected to increase dramatically in Namibia, with support for bush thinning and biomass utilisation coming from government, donors and commercial institutions.

Bush thinning operations need to be carried out carefully, to avoid causing environmental harm. Two government departments are responsible for authorising and monitoring bush harvesting activities – the Directorate of Forestry in the Ministry of Agriculture, Water and Forestry, and the Department of Environmental Affairs in the Ministry of Environment and Tourism. They administer a process which has been streamlined with the specific intention to avoid unnecessary time delays and high costs for farmers wishing to undertake bush thinning.

Guidelines in this book show what permits and authorisations are required, and the process to obtain them. The book includes a generic Environmental Management Plan that can be adapted as needed to obtain Environmental Clearance for a bush harvesting operation. Also, guidelines are provided on best practices in bush thinning.

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Appendix 9 Potential positive and negative environmental impacts of aftercare.

The colours in the first column indicate recommended (green), less desirable (yellow) and not recommended (red) aftercare methods from an environmental perspective.

Aftercare method	Appropriate harvesting method	Potential for successful control of target plants	Potential positive impacts	Potential negative impacts	Mitigation measures	Management considerations
Treatment of cut stump surfaces with registered arboricide	Mechanical or manual stem cutting or sawing than leaves a clear cut surface of harvested bushes	Good control of treated plants possible but newly established seedlings, re-sprouts (e.g. root suckers) following harvesting not controlled	Highly selective with least impact on non-target plants Minimal soil contamination Minimum soil disturbance Minimal disturbance of animals and birds because following directly after harvesting operations Effective for *Dichrostachys cinerea* control	Concern about current arboricide health issues for applicators[1] Chemical spills resulting in non-target plant impacts	Proper protective clothing and thorough training of labourers Training and proper equipment	Excellent supervision necessary Have to be applied within hours of harvesting to be effective

[1]The active ingredient Picloram is on FSC's current Restricted Pesticide list as a Suspected carcinogen (Cat. 2)(GHS) and Endocrine Disruptor (Cat. 2) (GHS). In Namibia known FSC certified producers such as the Cheetah Conservation Fund are using this arboricide because of lack of alternative registered arboricides currently available.

Aftercare method	Appropriate harvesting method	Potential for successful control of target plants	Potential positive impacts	Potential negative impacts	Mitigation measures	Management considerations
Foliar spot treatment of resprouting/emerging woody plants between 2-8 months after harvesting with a registered arboricide (e.g. arboricides with active ingredients such as picloram)	Any method	Good	Highly selective. Newly established problem seedlings after harvesting are also controlled Minimal soil contamination (although more than stem treatment) Minimum soil disturbance	Concern about current arboricide health issues for applicators Drift in windy conditions may cause non-target plant impacts	Proper protective clothing and thorough training of labourers Only spraying under low wind conditions	To be effective the plants to be controlled needs to have a fully expanded, green foliage cover, e.g. height between knee and hip height. Must not be stressed (drought).
Soil applied arboricides	Any method	Poor in dense situations. Improve in low density situations	Minimal soil disturbance	Long-term residual effects of arboricide May contaminate ground water resources Non-target plants may be affected Species such as *Dichrostachys cinerea* requires higher dose to be effective	Only apply where low densities of target plants occur and are evenly distributed Training and field supervision important to minimize arboricide amounts used	Soil type (texture) affects the dosage required

Aftercare method	Appropriate harvesting method	Potential for successful control of target plants	Potential positive impacts	Potential negative impacts	Mitigation measures	Management considerations
Manual uprooting of regrowth, saplings and seedlings (simply cutting/sawing of plants not effective)	Any method	Medium. Labour intensive and inefficient for controlling larger shrubs where underground parts needs to be removed Appropriate for small harvested areas	No chemicals used Highly selective Little soil disturbance Job creation	Labour intensive therefore increased risk of poaching, illegal collection of protected organisms, etc. Not effective against species such as *Dichrostachys cinerea* that readily coppice from exposed roots	Close supervision, training and strict rule enforcement	Not appropriate for large harvested areas due to slow control rate
Heavy mechanised machinery such as rollers, bulldozers, chains, etc.	Any method, but cut stumps may be a problem	Regrowth will only be suppressed temporary and will require re-application according to growth rate of coppice (e.g. every 3-5 years)	High quality browse is kept within reach of browsers	Soil disturbance and compaction (cumulative) Killing of slow moving animals and ground nesting birds Disturbance of wildlife through noise and dust pollution Not selective at small-scale (limited manoeuvrability) Continued competition of suppressed bushes with herbaceous layer	Proper training of operators Close supervision in the field Appropriate PPP Inspect aftercare areas and remove and flag sensitive animals and plants before operations	Can only be applied on flat areas without rocks

Aftercare method	Appropriate harvesting method	Potential for successful control of target plants	Potential positive impacts	Potential negative impacts	Mitigation measures	Management considerations
				Small scale pollution by leaking oil, fuels, grease, etc. Greenhouse gas emissions Loss of life and injuries from accidents	Slow down operation to allow slow-moving organisms to flee	
Fire	Can be used with any harvesting method	Depends on fuel load (dry grass), atmospheric conditions at the time of the burn and whether burning with or against the wind	Considered a natural method of controlling woody plants (i.e. no chemicals or machinery used) High quality browse is kept within reach of browsers Can be effective in combination with other methods such as selective foliar spraying	Fire may escape intended area and destroy grazing and property May kill or injure animals A drought year after the fire may result in rangeland degradation Seeds of species with long-lived seed banks such as *Dichrostachys cinerea* stimulated to germinate Only seedlings are effectively killed. Saplings and larger	Good preparations and adequate fire fighting equipment and management of the actual fire and aftermath	Only effective where a large enough fuel load accumulates Right climatic conditions and fuel loads should be chosen to prevent too hot fires that damage the canopies of large trees or too cold fires that fail to control regrowth Good rangeland management practises such as adequate resting essential after fire

Aftercare method	Appropriate harvesting method	Potential for successful control of target plants	Potential positive impacts	Potential negative impacts	Mitigation measures	Management considerations
				plants re-sprout, therefore fire needs to be repeated (e.g. every 3-5 years) Emissions of smoke and greenhouse gasses		Requires adequate fire fighting equipment and regulations must be followed
Browsers such as goats (game are considered too difficult to control to be effective as an aftercare method)	Any method	Poor. At best can browsers be expected to slow down regrowth rates May be effective against seedlings A combination of fire and browsers potentially more effective	Considered a biological method Generates an additional income	Browsers have feeding preferences and especially thorny encroacher species may be avoided while desirable broadleaved species are preferred May negatively impact on palatable grass species (goats are mixed feeders and also consume herbaceous plants)		Goats demands intense management and to sustain high stocking densities herding or fencing is required, which can be expensive Adequate preparations in terms of predator control, kraaling at night and animal health are required