Republic of Namibia

Ministry of Environment, Forestry and Tourism

National Strategy on the Sustainable Management of Bush Resources

2022-2027

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Acknowledgements

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Foreword

Sixty percent of Namibia's surface area is classified as tree and shrub savanna biome, which should be characterised by large, open expanses of grassland dotted with a predominance of thorn trees and bushes. Over the years, Namibia's "beloved land of savannahs" has steadily been covered by thorny and impenetrable bush with considerable negative impacts on biodiversity, soils, water availability, the productivity of the land and the livelihoods of our people. Bush encroachment has become a main indicator for land degradation and is a major climate change adaptation challenge for Namibians.

The overarching mandate of the Ministry of Environment, Forestry and Tourism is given by the Constitution and includes 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 […]*".

Thinning the bush is important to reduce biodiversity loss, adapt to the impacts of climate change and ensure food security in a country, which strongly depends on natural resources and agriculture. Benefits from rehabilitating and restoring of bush encroached land are estimated at N$76 billion over 25 years if 15.8 million hectares of land are thinned sustainably. These values arise from increasing groundwater recharge, enhancing land productivity, and using the biomass for different value chains.

The sustainable use of resources is entrenched in the Namibian Constitution and the Government of Namibia is committed to ensure that appropriate, sustainable bush harvesting practices are implemented to maximise the environmental benefits of bush harvesting. The National Strategy on the Sustainable Management of Bush Resources provides guidelines on the sustainable management of the resource base; re-establishing balanced, natural habitats and biodiversity; addressing land degradation and adapting to climate change to enhance the resilience of Namibia's communities and ecosystems.

MINISTRY OF ENVIRONMENT, FORESTRY AND TOURISM
REPUBLIC OF NAMIBIA
29 MAR 2022
THE MINISTER

Hon. Pohamba Shifeta

Minister of Environment, Forestry and Tourism

Preface

The extent of bush encroachment and its related negative impacts on biodiversity, water availability, land productivity, and the resilience of ecosystems and livelihoods requires urgent action. Unsustainable bush thinning methods intended to improve the carrying capacity of the land in the short term can worsen degradation and further threaten the resilience of ecosystems and their services. The restoration of 15.5 million hectares of encroached land is a national commitment presented in the NDP5, as well as one of Namibia's climate change mitigation and adaptation contributions to the UNFCCC Paris Agreement. Tackling the bush encroachment crisis is therefore a high-level adaptation priority for the Ministry of Environment, Forestry and Tourism.

This Strategy provides clarity and guidelines on the sustainable management and use of bush resources. It provides guidance on bush control and the development of bush value chains to ensure that the resource is used sustainably, that the development of the bush biomass sector benefits all Namibians and that the environmental benefits of bush control are enhanced. If done correctly, bush control can contribute to sustainable development, improved management of natural resources, enhanced ecosystem functionality and more resilient ecosystems, and enhanced biodiversity and habitats for wildlife and ultimately enhanced well-being of our people.

The Strategy on the Sustainable Management of Bush Resources can thus contribute to SDG 1 (No poverty), SDG 8 (Decent work & Economic Growth) by creating employment opportunities, SDG 9 (Industry, Innovation & Infrastructure) by creating innovative value chains as well as SDG 13 (Climate Action) and SDG 15 (Life on Earth) by ensuring the conservation, restoration, and sustainable use of terrestrial ecosystems (15.1), combatting desertification, and restoring degraded land and soil (15.3), reducing the degradation of natural habitats to halt the loss of biodiversity (15.5) and reducing the impact of invasive species by eradicating priority species (15.8).

Teofilus Nghitila

Executive Director

MINISTRY OF ENVIRONMENT, FORESTRY AND TOURISM
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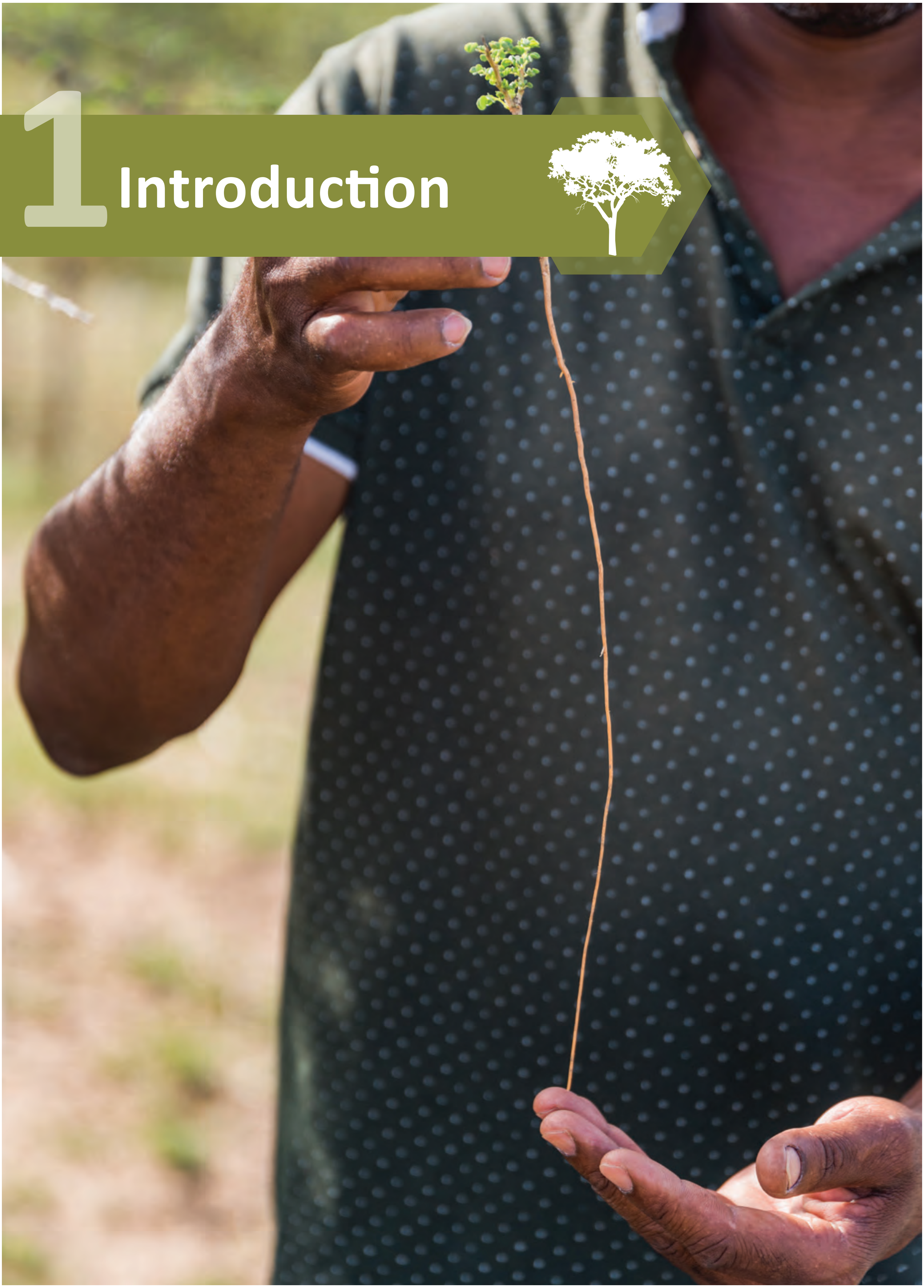
List of Abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
BAU	Business as Usual
BCBU	Bush Control and Biomass Utilisation
BE	Bush Equivalent
BIS	Bush Information System
BQT	Biomass Quantification Tool
CO_2	Carbon Dioxide
CBA	Cost Benefit Analysis
CBNRM	Community-Based Natural Resource Management
CBO	Community-Based Organisations
DAPEES	Directorate of Agricultural Production Extension and Engineering Services
DARD	Directorate of Agricultural Research and Development
DAS	De-bushing Advisory Service
DBN	Development Bank of Namibia
DoF	Directorate of Forestry
DSS	Decision Support System
ECC	Environmental Clearance Certificate
EIA	Environmental Impact Assessment
EIF	Environmental Investment Fund
EIS	Environmental Information System
EMP	Environmental Management Plan
ETTE	Evapotranspiration Tree Equivalent
FAO	Food and Agriculture Organisation
FMP	Forest Management Plan
FSC	Forest Stewardship Council
GHG	Greenhouse Gases
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ) GmbH
GPS	Global Positioning System
ha	hectares
IEC	International Electrotechnical Commission
IRLUP	Integrated Regional Land Use Plan
ISO	International Organisation for Standardisation
IUM	International University of Management
MAWLR	Ministry of Agriculture, Water and Land Reform
MDF	Medium Density Fibre
MEFT	Ministry of Environment, Forestry and Tourism
MIT	Ministry of Industrialisation and Trade
MME	Ministry of Mines and Energy
MoL	Ministry of Labour, Industrial Relations and Employment Creation
MURD	Ministry of Urban and Rural Development
MW	Megawatt
NACSO	Namibian Association of CBNRM Support Organisations
NamPower	Namibia Power Corporation
NAU	Namibia Agricultural Union
N-BiG	Namibia Biomass Industry Group
NBSAP	National Biodiversity Strategy and Action Plan
NCA	Namibia Charcoal Association
NCE	Namibian Chamber of Environment
NDC	Nationally Determined Contribution
NDP	National Development Plan
NDVI	Normalised Difference Vegetation Index
NGOs	Non-Governmental Organisations
NECFU	Namibia Emerging Commercial Farmers' Union
NIRP	National Integrated Resource Plan
NNFU	Namibia National Farmers' Union
NPC	National Planning Commission
NPI	Net Positive Impact
NRMP&S	National Rangeland Management Policy and Strategy
NSA	Namibia Statistics Agency
NSI	Namibia Standards Institution
NTA	Namibia Training Authority
NUST	Namibia University of Science and Technology
PES	Payments for Ecosystem Services
pH	Potential Hydrogen
PPO	Producers and Processors Organisation
RSA	Republic of South Africa
SAIEA	Southern African Institute for Environmental Assessment
SDG	Sustainable Development Goal
SOC	Soil Organic Carbon
SOPs	Standard Operating Procedures
TE	Tree Equivalent
TLS	Terrestrial-Based LiDAR
UAV	Unmanned Aerial Vehicle
UNAM	University of Namibia
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention on Combating Desertification
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction



Bush encroachment has been identified as a form of land degradation in Namibia (De Klerk 2004), threatening the provision of key ecosystem services, biodiversity, and the livelihoods of people. In Southern Africa, it is commonly referred to as "bush encroachment", although the term "bush thickening" is more appropriate since it involves indigenous woody species in their natural environment (Smit et al. 2015). Land users have implemented measures to reduce bush densities for decades: These small-scale efforts to address the bush encroachment problem had varying success and environmental impacts. There is growing interest from the private sector as well as national and international development institutions to promote bush value chains in Namibia. A dedicated framework must be established to ensure the optimal management and use of bush resources to safeguard the sustainability of the resource base, as well as environmental and socio-economic benefits of bush control.

Three elements justify the need for a Strategy on the Sustainable Management of Bush Resources:

1. Potentially unsustainable use of bush resources would hamper the ecological and environmental benefits of bush control and the rehabilitation of bush encroached land.
2. The existing legislative framework lacks clarity and vision on addressing bush-related issues, such as guidance on the utilisation of the resource in different land tenures, and there is no dedicated document specifically addressing bush resources.
3. It is important to address the bush encroachment problem and promote sustainable use of bush resources to achieve important international commitments on deforestation and afforestation, land degradation and desertification, climate change mitigation and adaptation, as well as conservation of biological diversity outlined in the Rio Conventions (UNFCCC, UNCBD and UNCCD).

The management of bush resources and bush value chain development is mentioned in various policies and regulations spanning from forestry to energy and industrial development. Differences within and between institutions on the governance of bush resources and their sustainable use are numerous.

The economic opportunities of using woody biomass for different value chains can lead to overutilisation. This necessitates clear guidelines on responsible thinning and on creating a balance between rehabilitating and maintaining savanna ecosystems while commercially using bush resources. The current governance framework provides a solid base for environmental safeguards. However, specific guidelines and definitions on harvesting based on environmental considerations along value chains are missing. A lack of guidelines on what is considered sustainable bush control in national regulations and policies creates barriers to both development and law enforcement on the ground, as major economic agents fail to understand the political and economic priorities.

If done correctly, the sustainable removal and use of excess bush biomass can have positive impacts on the environment and economy and does not contribute to further degradation. However, currently key actors of the sector face challenges and barriers that limit their capacity to undertake sustainable bush management. Guidance is required to support the sector in taking a sustainable path.

The ministry responsible for environment and forestry under its mandate as the regulator of natural resource use, promoting sustainable utilisation and maintaining ecosystems and biodiversity, provides, through this strategy, clarity and guidelines on the sustainable use of bush resources.

The strategy guides bush control and the development of bush value chains to ensure a positive ecological and socio-economic impact. Bush thinning to a predetermined scientifically established density instead of bush clearing is promoted. If done correctly, bush control can contribute to improved water and nutrient cycling, better soils, enhanced ecosystem functionality and more resilient ecosystems, and improved biodiversity in terms of species diversity - especially for plants and habitat for wildlife. It can also contribute to SDG13 (Climate action) and SDG15 (Life on earth) ensuring the conservation, restoration, and sustainable use of terrestrial ecosystems (15.1), combatting desertification, and restoring degraded land and soil (15.3), reducing the degradation of natural habitats to halt the loss of biodiversity (15.5) and reducing the impact of invasive species by eradicating priority species (15.8).

This strategy establishes the necessary guidance to ensure that bush resources are used sustainably, that the development of the bush biomass sector benefits all Namibians, and that the environmental benefits of bush control are enhanced.

Sustainable Utilisation of Bush Resources

Within the scope of this strategy, the term "sustainability" is understood based on the definition of the Brundtland Commission in 1992, defining sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable utilisation of bush resources refers to the reduction of excess bush in a holistic manner to maintain an optimum savanna ecosystem and enhance ecological, social and economic benefits.

1.1. Extent of Bush Encroachment in Namibia

Bush encroachment has been identified as a key driver of land degradation in Namibia, threatening the provision of ecosystem services, biodiversity, and the livelihoods of people. Land users have implemented measures to reduce bush densities for decades. Early explorers reported dense patches of bush in some areas, which suggests that thickening of bush is a natural phenomenon and part of the savanna ecosystem and Namibia's landscape (Cunningham 2014). There are several estimates of the extent of bush encroachment in Namibia. The 45 million hectares estimated by SAIEA (2016) are considered as the national bush encroachment status. From the estimated 45 million hectares, about 23% (10.5 million hectares) occur in Otjozondjupa (Hengari 2018).

Definition: Bush Encroachment

Bush encroachment is a global phenomenon. Across different bioclimatic zones, woody plants have displaced grasses. While trees dominate humid regions, unpalatable shrubs proliferate in arid regions. This is considered a type of degradation (Archer et al. 2017). In Southern Africa, it is commonly referred to as "bush encroachment", although the term "bush thickening" is more appropriate since it involves indigenous woody species in their natural environment (Smit et al. 2015).

Bush encroachment is generally considered as **"the invasion and/or thickening of aggressive undesired woody species, resulting in an imbalance of the grass-bush ratio, a decrease in biodiversity, a decrease in carrying capacity and concomitant economic losses"** (De Klerk 2004). In the Namibian context, bush encroachment is the increasing abundance of indigenous woody plants in savanna ecosystems. Invasion by non-indigenous species also occurs in Namibia mostly by alien species, sometimes called "invasive" species.

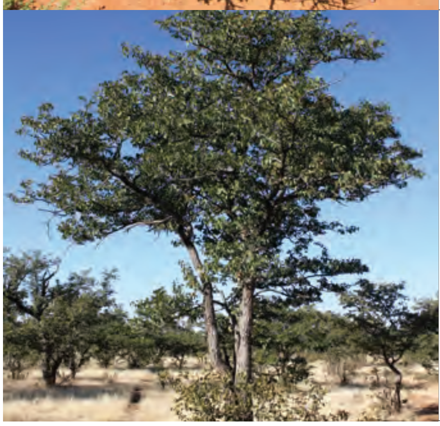
According to De Klerk (2004), an area is considered bush encroached when the numerical density of 1.5 m-high bush equivalents (BE) per hectares exceeds twice the average annual rainfall (in mm). It also depends on the dominant species and the soil conditions, with Sandveld requiring higher bush densities.

A bush equivalent (BE) is a bush of 1.5m in height: one dwarf shrub of 75 cm in height would be ½ BE, while a large tree of 4.5 m height would be 3 BE.

A study questioning more than 350 farmers all over Namibia indicated that bush encroachment has increased in severity over the years (Agra 2015). Due to the extent of bush encroachment in Namibia, it has become a separate indicator for land degradation in Namibia's Land Degradation Neutrality Target Setting (Hengari 2018).

Most thickening species in the world belong to the genus *Acacia*. The genus *Acacia* was reclassified into *Senegalia* and *Vachellia* for the African line, but the term *Acacia* is still widely used. The genus includes more than 900 species worldwide and is the second largest genus. In areas with poor soil, the nitrogen fixing abilities of *Acacias* can increase soil fertility, which allows them to gain a competitive advantage over other species (Lesoli et al. 2013). The main bush-thickening species in Namibia are outlined below. All these species are indigenous and considered important parts of their respective ecosystems. Some are protected but are encroaching in certain areas.

Table 1 *Bush thickening species in Namibia. Photo credits (NBRI): C. Mannheimer, B. Curtis, K. & S. Roberts and P. Horn*

	Scientific Name	**English**	**Afrikaans**	**Otjiherero / Oshiwambo**
	*Senegalia mellifera*	Black Thorn	Swarthaak	Omusaona / Omunkono
	*Vachellia reficiens*	Red Umbrella Thorn	Rooihaak	Omugondo / Omutsiyatsi
	*Terminalia sericea*	Silver cluster-leaf	Geelhout	Omugolo / Omusejasetu
	*Rhigozum trichotomum*	Three-thorn	Driedoring	Okatakambindu
	*Colophospermum mopane*	Mopane	Mopani	Omusati / Omutati

	Scientific Name	English	Afrikaans	Otjiherero / Oshiwambo
	*Dichrostachys cinerea*	Sickle Bush	Sekelbos	Ongete / Omutjete
	*Terminalia prunioides*	Purple-pod Terminalia	Deurmekaarbos	Omuhama
	*Vachellia luederitzii*	Kalahari Acacia / False Umbrella Thorn	Baster-haak-en-steek	Omushu
	*Vachellia nilotica*	Scented-pod Acacia	Lekkerruikpeul	Olufu / Omutyuula

In addition, the following species have been linked to bush encroachment:

- *Senegalia erubescens* (*Acacia erubescens*) (Blue Thorn / Yellow-Bark Acacia, Withaak, Omungongomwi) (De Klerk 2004)
- *Senegalia cinerea* (*Acacia fleckii*) (Blade Thorn) (De Klerk 2004)
- *Acacia tortilis* (Umbrella Thorn, Haak-en-steek, Orusu) (Joubert et al. n.d.)
- *Catophractes alexandrii* (Trumpet Thorn, Ghabbabos, Omukaravethi) (De Klerk 2004)
- *Lycium bosciifolium* (Bocksdorn, Brosdoring, Okahua) (Joubert et al. n.d.)
- *Protasparagus spp*. (Asparagus, Katdoring) (Joubert et al. n.d.)

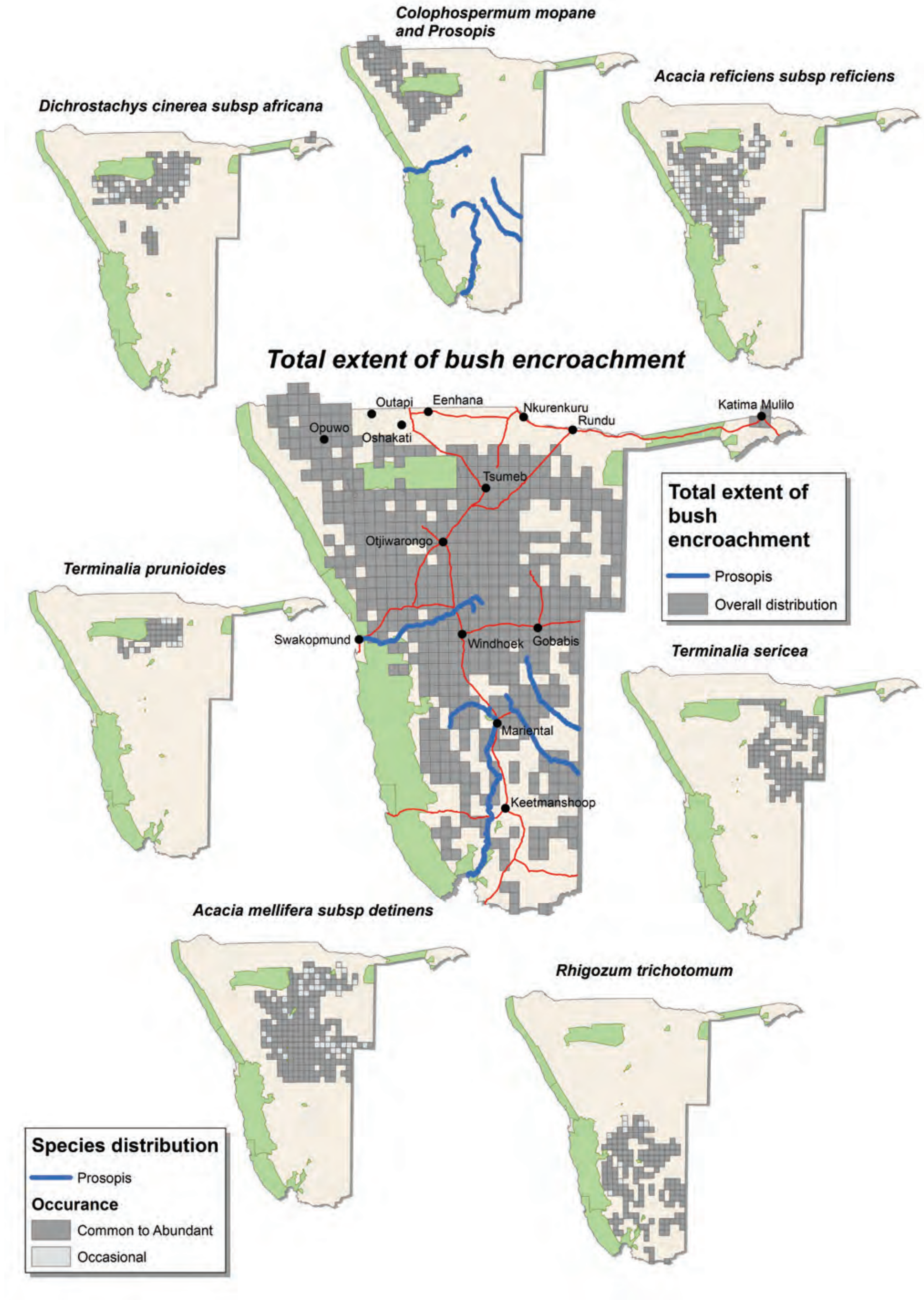


Figure 1 *Bush encroached areas in Namibia according to SAIEA 2016.*

Definition: Forests and Wooded Areas

Based on the definition of the FAO, "Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ" is considered forest.

Other wooded areas are "Land not classified as 'Forest', spanning more than 0.5 hectares; with trees higher than 5 metres and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent" (FAO 2020).

Namibia has five main biome types: (1) tree and shrub savannas, which account for around 60% of Namibia's surface area and include both broad-leaf and Acacia savannas characterised by "large, open expanses of grassland dotted with Acacia trees", (2) Namib desert, (3) Nama Karoo, (4) Succulent Karoo and (5) lakes and salt pans (Mendelsohn et al. 2002). Namibia's savannas are mixed savanna landscapes with woody plants and grasses. Based on the definitions of the FAO above, bush-thickened areas in Namibia are considered savanna and wooded areas under the governance of the Forest Act. In the context of this strategy, bush encroached areas are considered:

- woodland areas with more than 0.5 ha that are thickened against the capacity defined by the local conditions
- which have a relative over-abundance (80 – 90%) of species identified as encroaching and
- would not develop into a forest under the given circumstances.

In some cases, bush encroachment can also occur in forests. Any bush control in forests should be done in close cooperation and with close supervision by senior officials of the Directorate of Forestry in the Ministry of Environment, Forestry and Tourism.

1.2. Causes of Bush Encroachment

Key causes of bush encroachment in other countries of the world – such as changed fire regimes, grazing pressure caused by livestock and changes in climate – all apply to Southern Africa. However, additional drivers such as the strong decline of large browsers, past livestock pandemics (e.g. rinderpest), shifting human settlements, the extensive harvesting of woody biomass for firewood as well as land tenure and land-use patterns also influence the proliferation of bush in Southern Africa (O'Connor et al. 2014).

Primary and secondary determinants of bush encroachment include soil types and rainfall (primary determinants), as well as herbivory and fire (secondary determinants). These primary and secondary determinants are essential for the functioning of African savannas (O'Connor et al. 2014). Different factors including nitrogen deposition, atmospheric CO_2 concentrations, climate and grazing/browsing regimes interact with each other to constrain or promote the growth of thickening species. A change in just one of these factors may not be enough to trigger bush encroachment (Archer et al. 2017). These key drivers of bush encroachment are described in more detail below.

Grazers and Browsers

Grazing pressure by livestock can reduce fuel load and reduce the competition of grasses supporting the proliferation of bushes (O'Connor et al. 2014). It can support the development of woody seedlings by effectively dispersing seeds (Archer et al. 2017).

The artificial provision of water supports continuous grazing and reduced recovery phases for grasses (Hoffmann et al. 2010). The restrictions caused by fences can limit both wildlife and livestock movement, increasing grazing pressure in specific areas (Smit 2005).

Livestock can also displace browsers and seed predators impairing natural controls (Archer et al. 2017). Large browsers such as elephants, giraffes and rhinos can transform landscapes and considerably suppress woody thickening, but their populations have declined all over Southern Africa (O'Connor et al. 2014).

Climate

Precipitation above a certain threshold may favour woodlands and forests (Archer et al. 2017). The enhancement of woody biomass is limited by water availability in areas with less than 650 mm of rainfall per year. In wetter savanna ecosystems, external disturbances by large herbivores or fire are required to maintain a balance between woody plants and grasses (Tews et al 2004).

The thickening of woody plants depends on the seasonality of precipitation and rainfall infiltration. Frequent low-intensity rainfall and large rainfall events can favour woody plants with their deep roots, while grasses prefer small rainfall events and summer rains that moisten upper soil horizons (Archer et al. 2017). Variability in rainfall influences plant growth, recruitment and mortality. The high variability in semi-arid zones can support the enhancement of woody plants (Archer et al. 2017).

Fire

Fire is a natural phenomenon responsible for the maintenance of savanna ecosystems. It is a key ecological process regulating vegetation structure and species composition (Nepolo & Mapaure 2012). Fires suppress woody plants and benefit grasses (Roques et al. 2001). They have been used by indigenous communities to renew pasture when enough fuel load and litter has accumulated (Sheuyange et al. 2012).

The active suppression of fire and overgrazing, which reduces the fuel load, encourages the thickening of woody species. A lack of intense fires encourages saplings to grow and escape the fire flame zone, after which they may become fire resistant (Hare et al. 2020).

Topography and Soils

Grasses and woody plants use different soil resources. The roots of woody plants reach deeper, while the roots of grasses have a dense, fibrous system in limited depths exploiting the upper layers of the soil where nutrients and water concentrate (Archer et al. 2017). As a result, surface soils with a fine texture and shallow soils favour grasses. Deep and coarse soils with fast infiltration of water and nutrient leaching favour woody plants (ibid).

In highly fertile patches, the establishment of bush may be constrained due to the increasing competitiveness of the grass layer and herbivores attracted to the patch (Porensky & Veblen 2011). Slopes can cause water and nutrients to accumulate downslope and can encourage higher densities of woody plants (Archer et al. 2017).

Atmospheric CO_2

Atmospheric CO_2 has increased over time. Accelerated growth of woody plants caused by higher atmospheric CO_2 can create ecological opportunities (Archer et al. 2017). The growth efficiency of C3 plants, which includes woody species, under elevated CO_2 concentrations increases by 20 – 35% while grasses only increase by around 10%, (Seebauer et al. 2019). Most woody plants are particularly vulnerable as saplings and become very resilient to external stress – such as climatic events, fire and browsing – at a certain level of maturity. Increased sapling growth due to high CO_2 concentrations increases the chances of woody saplings escaping this vulnerable phase (Archer et al. 2017).

Increased levels of CO_2 can also encourage the fast regrowth of woody plants after the removal of above-ground biomass. Warmer temperatures caused by climate change – and the resulting absence of severe frost – can also encourage the proliferation of bush (O'Connor et al. 2014).

1.3. Effects of Bush Encroachment

Bush can have positive effects on an ecosystem and support important ecological processes. However, the extreme thickening of bush is often associated with considerable negative impacts. A summary of positive and negative impacts of bush is presented in Figure 2. A detailed account of positive and negative impacts can be found in Annex 1.

Figure 2 *Positive and negative impacts of bush thickening.*

Positive Impacts

Habitats: Bush creates unique and diverse habitats and provides browse for livestock and wildlife (Smit 2004). Open savanna landscapes with islands of dense thickets may have the highest overall biodiversity (Smit 2005).

Soil Fertility: Trees can have a positive impact by enriching the soil under their canopy through the decomposition of organic matter (Smit 2005). The nutrients available to plants are higher in encroached landscapes due to the nitrogen fixing ability of plants in the Fabaceae family. Bush with its deep roots can access nutrients from deeper levels and therefore acts as a nutrient recycler (Smit 2004).

Soil Hydraulic Properties: Infiltration of rainwater is highest close to the canopies of woody plants, due to the plant litter underneath the canopy. The extensive distribution of roots creates macropores, which have a positive effect on infiltration (Eldridge et al. 2015).

Economic Opportunities: Bush encroachment can promote land-uses based on the commercial use of woody biomass (below a diameter of 18cm) to diversify the economy and generate income (Archer et al. 2017).

Negative Impacts

Hydrogeology: Bush has a higher air turbulence and lower albedo increasing potential evapotranspiration. It also has a higher canopy interception of rain. As a result, bush encroachment can reduce groundwater recharge and thus underground water levels (Archer et al. 2017).

Biodiversity: Bush encroachment can shift landscapes from grassland to shrub or tree savannas and these savannas to woodlands or shrublands. As a result, ecosystems and species are endangered in many parts of the world (Archer et al. 2017).

Soils: Bush encroachment and the resulting increase in biomass can change soil microbial communities and slow decomposition ratios and thus soil fertility (Buyer et al. 2016). Bare areas between bushes in encroached landscapes can lead to soil erosion (Manjoro et al. 2012).

Carbon Sequestration: There is considerable scientific debate about carbon stored in bush encroached land and savanna ecosystems. Bush encroachment redistributes carbon among key terrestrial pools with arid areas likely becoming net sources of carbon, and areas with higher rainfall likely becoming net sinks (Archer et al. 2017). There is evidence that savanna ecosystems store more carbon due to higher soil organic carbon and that these can offset the emissions from removing the biomass. A detailed study for Namibia is required.

Economic & Social: The grazing capacity in many Southern African countries has considerably declined making livestock production economically unviable (Smit 2004). Bush encroachment can fragment landscapes and reduce the carrying capacity of rangelands (Blaum et al. 2007). In wetter areas, reductions in carrying capacity range between 40% and 50%. In arid environments, the carrying capacity can decline between 70% and 90% (Dannhauser & Jordaan 2015). The resulting degradation of rangelands can lead to food insecurities and poverty (Lesoli et al. 2013). In addition, bush encroached landscapes are often less aesthetically pleasing and have a reduced aesthetic value for tourism (Lesoli et al. 2013).

1.4. Bush Thinning and Value Chains

Due to the considerable negative impacts of bush encroachment, reducing bush densities through selective thinning or harvesting and the subsequent use of the biomass have become key strategies to rehabilitate land while promoting economic growth.

Reducing Bush Densities

Various methods for bush control are practiced in Namibia. Such methods include large-scale mechanical control, heavily mechanised control, manual and semi-mechanised control and chemical control. Other preventative measures to avoid encroachment in savanna are also used and include burning or controlled fire, biological control and manual control. The effectiveness of various bush thinning methods varies and can be difficult to trace due to a lack of controlled, closely monitored and scientific studies (SAIEA 2016). Farmers' decisions on bush control methods normally depend on their preferences and/or affordability. An overview of bush control methods is presented below. Additional information on the impacts on soils, regrowth rate and possible mitigation measures is discussed in Annex 3.

Conventional Medium to Large-Scale Mechanical Control

Conventional bush control techniques often use heavy machinery to thin or clear the bush. This involves the use of bush rollers on frontend loaders, mulching machines mounted to excavators, bulldozers, tractors or graders with blades as well as chains mounted between two tractors or bulldozers (De Wet 2015). Depending on the equipment used, the woody biomass can be used for different value chains (Van Oudtshoorn 2015).

Heavily Mechanised Bush Control

Highly mechanised thinning of bush uses skidsteer harvesters with horizontal rotary cutters or sawblades, three-wheel loaders with a buncher and hydraulic cutters, hydraulic grabs and or buncher with blade cutter, hydraulic grab and tree pullers as well as combined harvesters and grinders on tracks with shuttle buckets (De Wet 2015). These machines offer a relatively high level of selectivity for the removal of bush.

Manual and Semi-Mechanised Control

Manual methods are mainly used to control woody plants in small areas. These measures are very selective and minimise damage for desirable plants but are time and labour intensive and must be conducted several times to ensure minimum re-thickening (Lesoli et al. 2013). Manual thinning uses axes, pangas, pruning tools or saws, handheld chainsaws, multi-circular saws, tractor drawn slashers and trolleys with type or circular cutters (De Wet 2015).

Chemical Control

Arboricides have different chemical properties which make them applicable for different soils, climates and application options and have different effects on the environment (Lesoli et al. 2013).

1. Soil Applied Arboricides are applied to the soil and absorbed by the roots. They are mostly based on bromacil, tebuthiuron or ethidimuron. Concentrations between 20% and 70% are available in the form of granules, liquid or a wetable powder (ibid). They are mainly applied by hand to the soil around the stem of the plant. Water infiltrating the soil dissolves the chemical and transports it to the root zone (Van Oudtshoorn 2015). Some can be used for aerial application (Lesoli et al. 2013).
2. Plant Applied Arboricides which are sprayed onto the plant and absorbed by the foliage or other parts such as stems are mainly based on picloram, 2.4-D and 2.4.5-T (Lesoli et al. 2013). They can be applied selectively by hand or unselectively through aerial spraying (Van Oudtshoorn 2015). This includes Basal Stem Application, where the lower 30cm of the stem and uncovered roots are treated, and Frill Application, where the chemicals are applied to cuts created by an axe (ibid).

The removal of bush creates a vacuum which will be filled by other bushes that are sometimes more aggressive. This effect can be reduced by having a competitive grass layer and retaining large bushes that suppress regrowth. **Thus, bush thinning is the desired method of bush control.** The higher the intensity of initial control, the higher the potential re-thickening. The land can only remain productive and in a desirable state by managing re-encroachment with a post-harvest treatment programme (Smit et al. 2015). A prerequisite of every post-harvest treatment programme should be responsible rangeland management (De Klerk 2004). Some key post-harvest treatments are outlined below. More detailed information on individual methods can be found in Annex 3.

Definition: Post-Harvest Treatments

Post-harvest treatment measures include all measures to contain the regrowth of bush after initial bush control, regardless of whether the bush is harvested for commercial use or to restore land.

Once the average tree density exceeds 75% of the maximum potential BE/ha, the land is considered re-encroached and in need for another bush control operation (Van der Waal & Stoldt 2020).

Controlled Fire

Fire is a part of savannas and responsible for the maintenance of the savanna ecosystems. It is a key ecological process regulating vegetation structure and species composition (Nepolo & Mapaure 2012). A fire regime includes the frequency, intensity and seasonality of fire (Lesoli et al. 2013). Different woody plants have a different sensitivity to fire: While some species may be very sensitive to fire, others may be resistant or encouraged to germinate. However, in many cases, a high intensity fire can control bush seedlings, coppice, or maintain woody plants at a specific height for the use of browsers. It is better suited for areas with considerable rainfall and good soil moisture to support sufficient fuel load for regular fires (Lesoli et al. 2013). Stem Burning, the use of a small, low intensity fire around the stems of the woody species, allows to selectively kill trees. The long application of heat can severely damage the bark and buds (Smit n.d.).

Fire should be applied close to the beginning of the growing season and repeated every 1 to 5 years depending on the fuel load. FSC recommends every 5 years.

Biological Control

Biological control measures use living organisms to reduce the reproductive capacity, growth, and effects of woody plants (Lesoli et al. 2013). Biological control can involve the introduction of grazers, browsers, invertebrates, or diseases. The main aim of biocontrol is to ensure woody species can reproduce and grow but do not aggressively thicken (ibid). In Namibia, Boer Goats have been used for bush control as the intensity and frequency of their browsing can be managed.

Biological control must be applied continuously if sufficient forage is available.

Mechanical Control

The use of heavy machinery for post-harvest treatment purposes is rare but it may be used after chemical control (e.g. with soil applied chemicals) to remove the dead bushes or trees.

Mechanical control must be done 3 to 4 times annually for up to two years after bush control.

Manual Control

Manual methods for post-harvest treatment involve the digging out of roots as well as manually removing coppice or saplings e.g. with a mattock or Tree Popper (Joubert & Zimmermann 2017).

The removal of coppice must be repeated 3 to 4 times a year for up to 2 years after bush control.

Chemical Control

Although soil-applied and plant-applied chemicals can be used as post-harvest treatment to control heavy re-sprouting after mechanical control or to control seedlings after fire (Lesoli et al. 2013), cut-stump application is the most viable option due to the costs of chemical control. During cut-stump application, chemicals are applied on freshly cut stumps (Van Oudtshoorn 2015). Foliar application to coppice or stems is also used to control re-growth.

Soil-applied chemicals must be applied before the active growth of the plant. Cut-stump application is done directly after mechanical or manual control. Foliar application is done in the active growing season. In most cases no repeat treatments are necessary, but follow-ups may be required.

Reseeding & Inter-Seeding

Bush control should include top-down and bottom-up measures to ensure the maintenance of specific densities and minimise further densification (Woods et al. 2012). Sowing of perennial grasses can increase competition and reduce bush density more than thinning alone (O'Connor et al. 2014). The seeds can be dispersed by livestock – by mixing the seeds into their feed – which is the most cost effective, or by creating seedcakes, seed bombs or blocks by mixing the seeds with manure, biochar and other growth enhancers. They can also be dispersed with drones (Van der Waal & Stoldt 2020).

Seeding should be an ongoing intervention and performed in the wet season.

Soil Enhancement

The removal of biomass can have a negative impact on the soil – the severity depending on the initial bush control method used. To speed up the restoration of soil fertility, minerals removed through the harvesting of bush must be returned (Zimmermann et al. 2017). This can be achieved by using by-products of the initial thinning operation or different value chains such as bush filters or brush packing, wood ash, wood acid, charcoal or biochar.

Soil enhancement should be a continuous process. Brush packing should be done before the rainy season, while wood ash or similar methods are applied in autumn or spring.

Grazing Management

Following bush control efforts, the treated area must rest to ensure recovery of the herbaceous layer. A sustainable grazing or veld management programme should be developed to control re-growth (Dannhauser & Jordaan 2015).

Grazing management is an ongoing process and must be adapted to the growth stages of the grass.

Pruning

After the initial thinning of areas with thick bush, the re-growth of the bush often has a different structure and species composition than the original stands (Smit et al. 2015, Cunningham & Detering 2017). Harvested single stem trees coppice after harvesting and become multi-stemmed trees. To use the regrowth for different value chains, these bushes or trees require pruning like plantation forestry (Cunningham & Detering 2017).

Pruning should be done in the growing season.

Bush Value Chains: Using the Excess Bush Biomass

The key aim of bush control should be the rehabilitation of the savanna ecosystem with both woody species and grasses to create balanced natural habitats and biodiversity. Bush value chains emerged as a solution for an otherwise discarded side product of rehabilitation efforts. **Maintaining a diverse landscape and large trees to enhance competitive controls is a priority, and the cutting of large trees for different value chains is not considered bush control.**

Farmers and independent companies have ventured into this growing economic sector. Current value chains using bush resources mainly consist of charcoal for exports, firewood for local communities, and small-scale production of compressed firewood and wood chips. More details on value chains are provided in Annex 2. New value chains are being researched and developed. The development of bush-based industries in Namibia is important to drive rehabilitation efforts to sustainably finance bush thinning for restoration. The large quantity of available biomass provides considerable economic opportunities and drives the development of these value chains (Trede & Pratt 2015).



Figure 3 *Bush-based biomass products, from left to right – animal feed, charcoal and wood chips. Photo credit: ©GIZ / Tim Brunauer*

1.5. Analysis of Potential Scenarios

Due to the extent of bush encroachment in Namibia, the negative impacts largely outweigh potential environmental and economic benefits. Bush encroachment has become a key indicator of land degradation. Bush thinning is required to bring back a balance between grass and woody plants and contribute to enhanced biodiversity and landscape rehabilitation (MEFT 2015, MEFT 2014b, De Klerk 2004). It is also expected to substantially contribute to increasing resilience to climate change, particularly in rural areas, and thus achieving key adaptation goals (MEFT 2015a), a priority of Namibia. Bush thinning can contribute to enhancing the resilience of communities and ecosystems by improving water-use efficiency, reducing the vulnerability to droughts, improving land productivity for diverse land uses and ensuring food security in a country in which most of the population relies on natural resources and agriculture (Reid et al. 2008).

The Economics of Land Degradation study conducted by Birch et al. in 2015 estimated benefits for the Namibian economy at N$76 billion over 25 years if 15.8 million hectares of land are thinned sustainably. An estimated N$6 billion will come from increased livestock production, N$15 billion from different biomass value chains (e.g. charcoal, electricity production and firewood) and about N$51 billion from an increase in groundwater recharge (Birch et al. 2015).

The nature of the regulatory framework provided by the government will determine to what extent these efforts contribute to ecological rehabilitation and restoration. The following scenarios are possible.

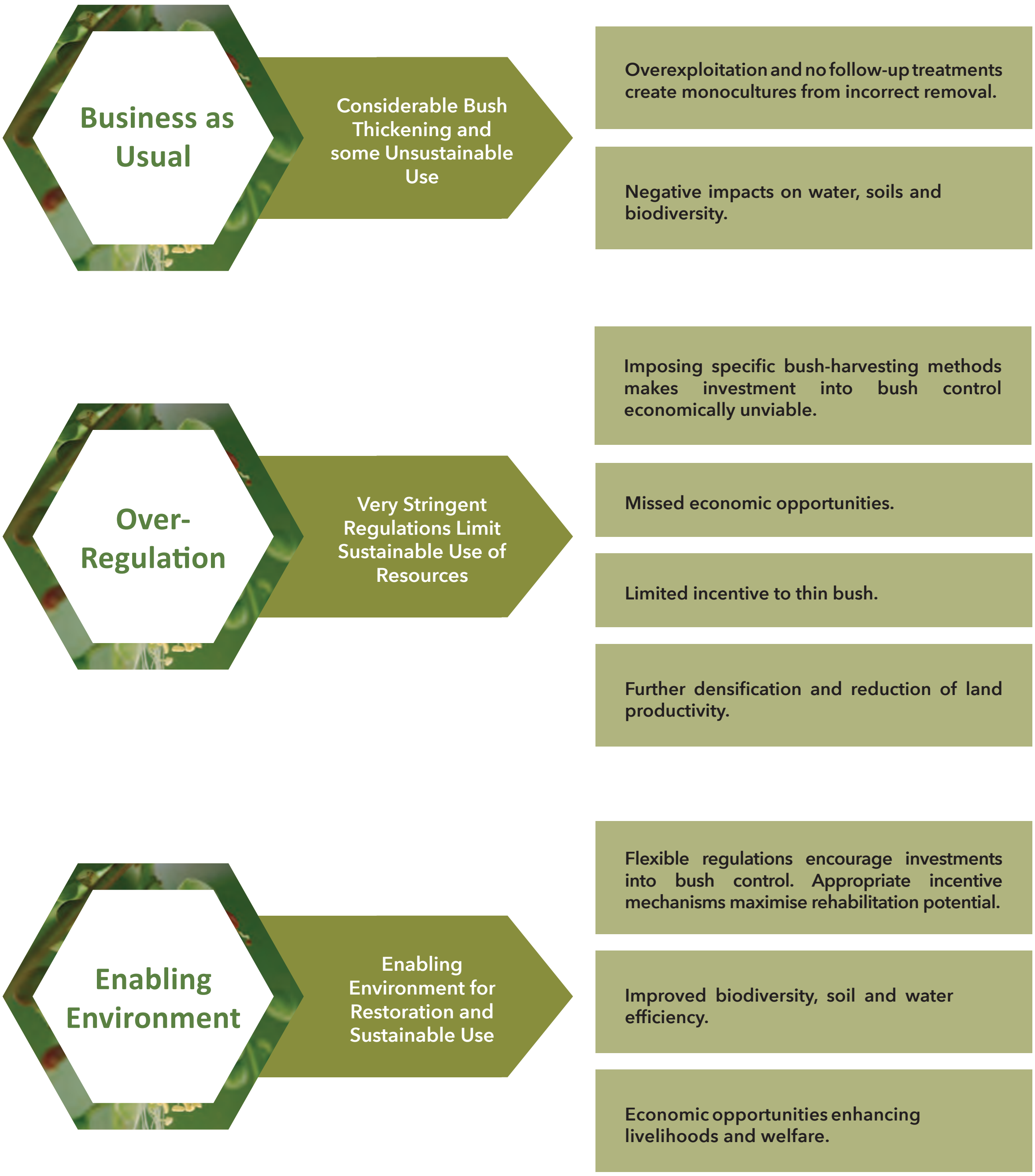
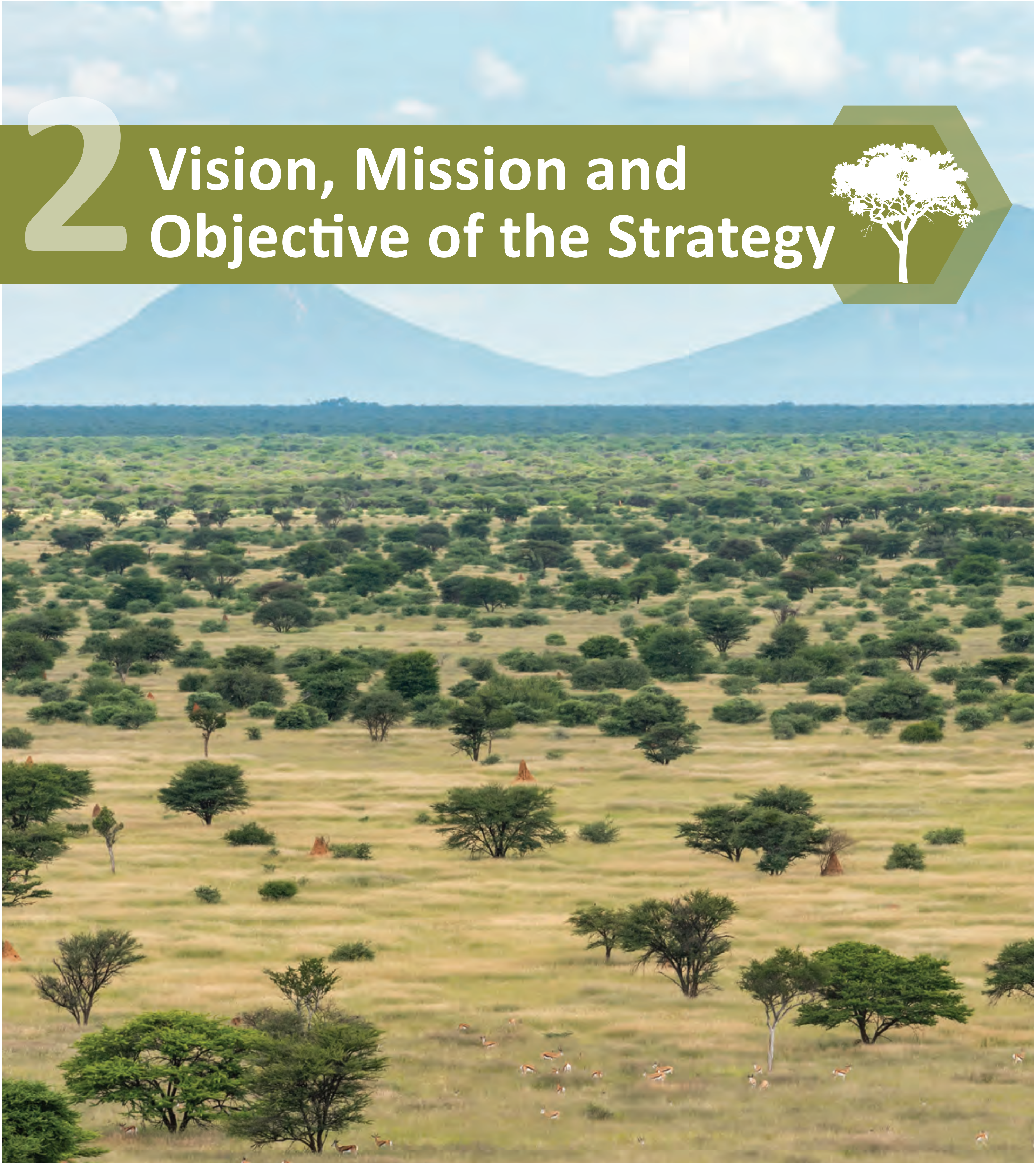


Figure 4 *Potential scenarios surrounding the governance of bush resources.*

This strategy provides clarity and guidelines on the sustainable management and use of bush resources. It guides bush control and the development of bush value chains to ensure a positive ecological and socio-economic impact. It establishes the necessary guidance to ensure that the resource is used sustainably, that the development of the bush biomass sector benefits all Namibians and that the environmental benefits of bush control are enhanced.

2 Vision, Mission and Objective of the Strategy



2.1 Vision

Improved savanna ecosystems through bush control to maximise ecological and environmental benefits and ensure the sustainability of the resource base.

2.2 Mission

Promote and facilitate the controlled thinning of bush biomass to encourage the restoration of ecosystems and maximise socio-economic and environmental benefits.

2.3 Overarching Objective

The Strategy aims at providing guidance and clarity on the environmentally, economically and socially sustainable management of bush resources in Namibia. It defines the environmental and ecological benefits and conditions for the rehabilitation of degraded land and the development of bush value chains. This Strategy also aims to guide key stakeholders on responsible bush control and bush value chains to ensure a sustainable resource base maximising environmental, social and economic benefits.

It complements the efforts of other institutions promoting the rehabilitation of degraded land and the development of bush value chains by

- providing a national reference and guidance for the sustainable management of bush resources,
- sharing the vision and clarifying the mandate of the MEFT in addressing bush encroachment in Namibia,
- clarifying the existing guiding framework for different bush resource extraction activities.

2.4 Guiding Principles

The MEFT approach to bush control and the sustainable use of bush resources is guided by Article 95(l) of the Constitution: "Maintenance of ecosystems, essential ecological processes and biological diversity and utilisation of living natural resources on a sustainable basis for the benefit of all Namibians" and the Ministry's Strategic Pillars (Strategic Plan 17/18-21/22) of Environmental Sustainability, Economic Progression and Rural Sustainable Development. The guiding principles of this strategy also reflect the commitments of the MEFT to international conventions such as the UNFCCC, UNCBD and UNCCD.

Principle 1: Maintaining of ecosystems, essential ecological processes and biological diversity
Addressing bush encroachment and developing bush value chains must be guided by an overarching consideration for the maintenance of ecosystems and biodiversity, as well as the rehabilitation of degraded land. The control over and guidance on the sustainable management of bush resources will ensure the maximisation of environmental benefits from bush thinning and the adequate protection and maintenance of biodiversity.

Principle 2: Ensuring the sustainable management of natural resources
The sustainable utilisation of living natural resources underpins all nature-based development initiatives in Namibia and applies to bush control and the use of bush resources in line with land rehabilitation targets. This entails rigorous monitoring and evaluation to ensure control over extraction rates and addressing potential long-term degradation concerns well in advance.

Principle 3: Promoting economic progression and sustainable development
The MEFT supports economic development that is socially and environmentally sound and will contribute to creating an enabling environment for sustainable and profitable bush resource use to the benefit of Namibians. More specifically, the MEFT recognises the potential of bush resources to contribute to rural sustainable development.

Principle 4: Enhancing resilience and adaptation to climate change
The MEFT recognises the potential benefits of bush control and the subsequent use of the resource to improve the adaptive capacity and resilience of communities to climate change. It supports the development of a bush-based biomass sector considering both challenges and opportunities created by climate change impacts.

Principle 5: Promoting a low-carbon development pathway
Namibia has committed to support global climate change mitigation by enhancing its carbon sinks and limiting its emissions of greenhouse gases under the Paris Agreement. Hence this Strategy encourages that bush control and the sustainable use of bush should strive towards this commitment.

Principle 6: Equity and inclusivity
The principles of inclusivity and social justice are essential to ensure that all Namibians can equally benefit from the sustainable use of bush resources. The management of this resource and its various uses, as well as the multiple benefits it can create, must therefore ensure fair and equitable treatment for all members of the Namibian society, especially for the previously disadvantaged, including women and youth, vulnerable populations and minorities.

Principle 7: Cross-sectoral cooperation, coordination and stakeholder participation
Bush control and the development of bush value chains involves a wide array of sectors and stakeholders at institutional, local and private sector levels. The implementation of this strategy will therefore require close coordination with other institutional actors and ministries, as well as the participation of key stakeholders.

3 Methodology of Stategy Formulation

Figure 5 *Institutional members of the Working Group.*

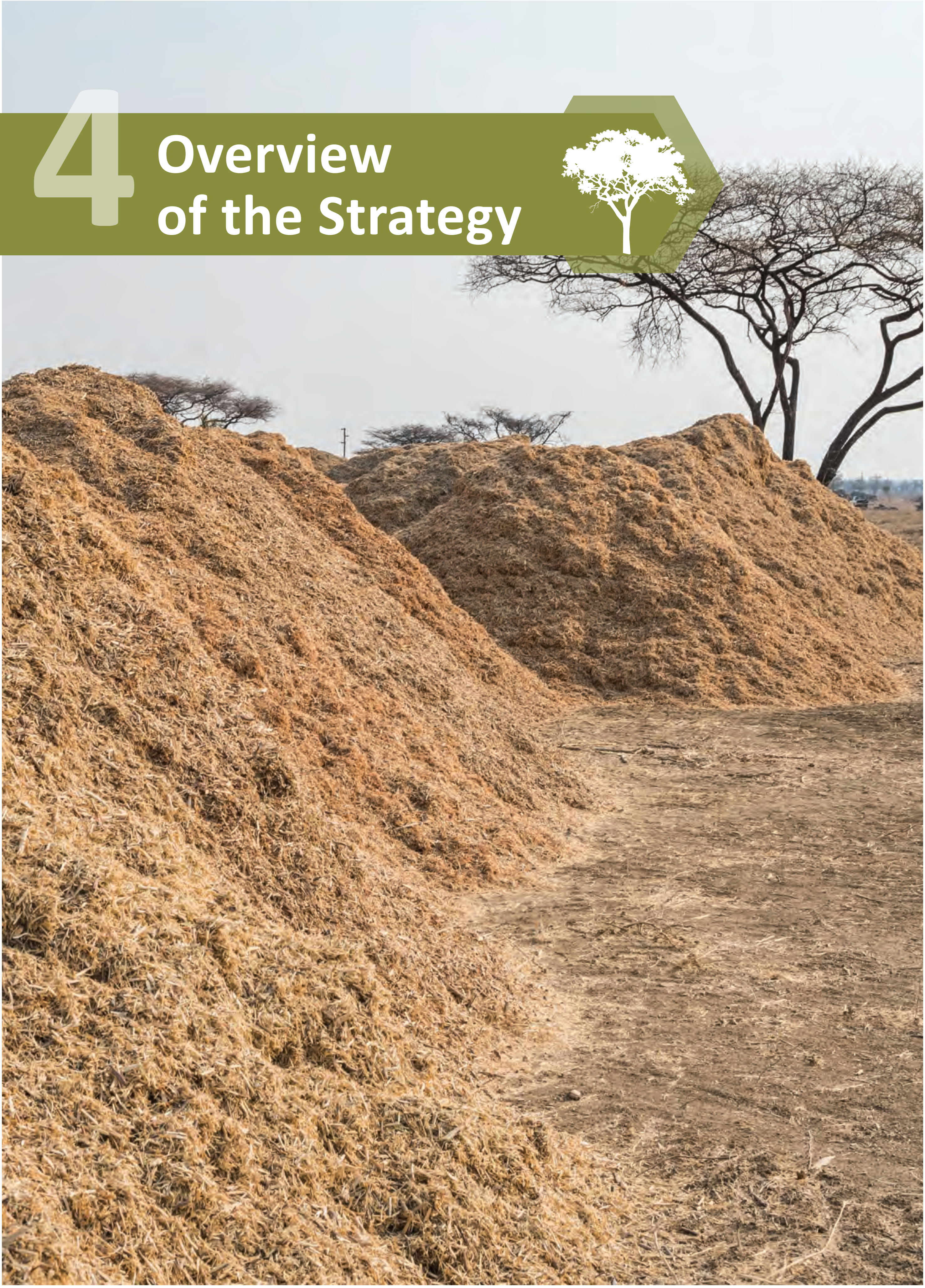
The process of developing a guiding framework for bush resource use started with the development of a scoping report on the existing governance structure which highlighted key gaps and challenges. Based on the findings of the scoping report, the development of a guiding document was initiated through a consultative and participatory process.

After initial consultations with key stakeholders and ministries, a Working Group was established to guide the strategy development process. The Working Group was constituted of key stakeholders within the government, civil society and private sector to ensure the interests of different institutions and needs of the industry are addressed. In addition, separate thematic talks e.g. to environmental NGOs and on bush value chains and industrialisation, were organised to address key issues.

A Task Force within the Ministry of Environment, Forestry and Tourism (MEFT) – including the Department of Forestry and Environmental Affairs, Scientific Services and National Parks – was established to ensure continuous engagement and feedback during the strategy drafting process and the alignment of the document with the interests and mandate of the ministry.

This strategy brings together biomass industry experiences, research and different efforts undertaken in Namibia, which have been published over the years, and is based on an extensive literature review.

4 Overview of the Strategy



4.1 Structure

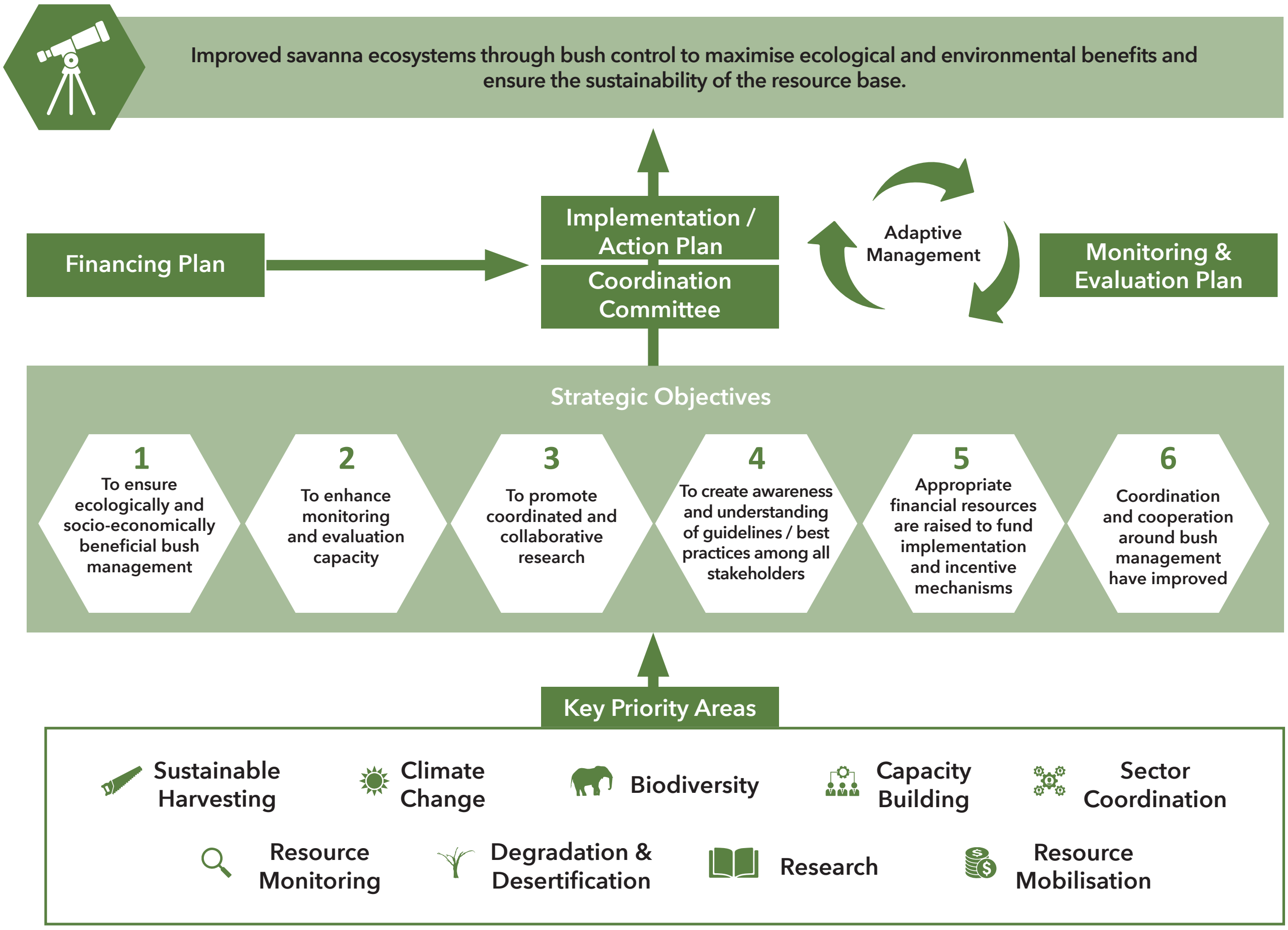


Figure 6 *Overview of the structure of the strategy.*

4.2 Institutional Arrangements: Strategy Alignment

This strategy is aligned with policies, strategic documents and international environmental agreements in different sectors and under multiple ministries.

By providing clarity, promoting – and in turn enabling – sustainable harvesting of excessive bush and appropriate post-harvesting practices, the strategy is in line with the objectives of the Environmental Assessment Policy, the UNCBD and the NBSAP II, all under MEFT mandate. The strategy outlines how sustainable bush control can contribute to the objectives of the UNCCD and Namibia's Third Programme under the UNCCD, as well as the NRMP&S on land restoration, rehabilitation and rangeland management.

The strategy is also in line with policies encouraging the sustainable use of bush resources as well as national development goals under the NDP and Harambee Prosperity Plan. It is in line with the National Development Forest Policy, which encourages bush thinning for charcoal production to improve range productivity and supplement income from livestock production, and the national development plan, which promotes bush thinning to increase livestock numbers and improve rangelands. The Harambee Prosperity Plan II (2021 – 2026) considers Namibia to have excellent biomass energy potential and includes the 40 MW Biomass Bush-to-Electricity Project.

By further enabling the development of sustainable and environmentally sound bush value chains, the strategy supports the realisation of the objectives of the Fifth National Development Plan, the Growth at Home Strategy, the Poverty Reduction Strategy and the National Development Forest Policy – amongst others. The vision, objectives and measures for the sustainable use of bush resources proposed in this strategy are aligned with key legislative instruments applicable to any activities within the bush biomass sector. Major legislation to consider for this strategy are the Forest Act and Forestry Regulations, the Environmental Assessment Act, the Labour Act as well as legally binding international commitments under the UNCCD, UNCBD, the Kyoto Protocol and Paris Agreement's NDC under the UNFCCC. The strategy is aligned with the following key policies and plans:

Table 2 *Alignment with key policies and plans*

Environmental Assessment Policy	The objectives supported by the policy include the maintenance of ecosystems and related ecological processes, those important for water supply, food production, health, tourism and sustainable development. It supports the wise utilisation of non-renewable resources and advancing biological diversity by ensuring the survival and promoting the conservation of the natural habitat of all species of fauna and flora. It defines environmental assessment procedure guidelines. The policy encourages the sustainable use of resources. Bush control can contribute to other objectives such as maintaining ecological processes around water supply, food production, tourism and sustainable development and conserving/improving biological diversity.
UNFCCC / Paris Agreement and NDCs	Focus on improving the ability to adapt to climate change impacts, enhancing resilience and promoting low-carbon emission development pathways. Namibia's Nationally Determined Contribution (NDC) targets emission reductions of **91%** compared to BAU by 2030. The NDC includes the development of a biomass power plant of 40MW that will contribute to **5%** of the GHG mitigation effort in the energy sector and the restoration of **15.5 million ha** of grassland and improvement of soil carbon through bush thinning, which will contribute **12%** to Namibia's mitigation effort in the AFOLU sector.
UNCBD and NBSAP II	The Convention on Biological Diversity deals with the restoration and rehabilitation of degraded ecosystems as well as the prevention, control and eradication of alien species that "threaten ecosystems, habitats or species". Key goals and targets of NBSAP II 2013 – 2022 include sound rangeland and sustainable forest management (Target 6), reviewing invasive alien species (Target 8) and restoring and safeguarding ecosystems that provide essential services and contribute to health, livelihoods and wellbeing (Target 22).
UNCCD and Third Programme	Namibia is also among the 120 countries to have engaged with the Land Degradation Neutrality target setting programme under the UNCCD, targeting to reduce bush thickening on 18,880 km^2 between 2000 and 2040. In its third programme to implement under the UNCCD (2014 – 2024), which includes Namibia's Land Degradation Neutrality Objectives, Namibia also addresses water degradation and the "lowering of water tables and desiccation of springs through invader bush species". The programme encourages the sustainable use, "value addition and development of the value chain for products" to drive bush thinning efforts.
National Development Forest Policy	A key aim of the National Forest Policy is "to realise maximum and efficient use of the multiple products and services of the forests" and "maintain the ecological functions such as the conservation of biological diversity, soil and water resources, unique ecosystems and landscapes". The policy aims to create rural development by "empowering farmers and local communities to manage forest resources on a sustainable basis", increase benefits from national woodlands, "create favourable conditions to attract investment in small and medium industry based on wood and non-wood forest raw materials and implement innovative land-use strategies including agroforestry". Sustainable market and trade in forest products should be encouraged. The National Forest Policy encourages bush thinning for charcoal production on freehold land to improve range productivity and supplement income from livestock production.
National Rangeland Management Policy and Strategy	The NRMP&S outlines the current condition of Namibia's rangelands, measures to optimise sustainable production per ha, rangeland management on communal land and incentives for farmers to improve rangeland. The NRMP&S explicitly mentions the need for a Bush Encroachment Management Policy. Under this policy the aim of bush control is land rehabilitation and increased carrying capacity. It sets land rehabilitation and improvement of rangeland management as national development objectives. One of the objectives of the NRMP&S is the reversal of the adverse effects of bush encroachment. It provides suggestions for bush control measures. In addition, the three Namibian Agricultural Farmers' Unions together with the Ministry of Agriculture, Water and Land Reform developed a National Strategy to Revive the Namibian Livestock Industry, which includes improved rangeland management practices, bush thinning as well as landscape rehydration.

Growth at Home	Growth at Home provides a road map for the execution of the National Industrial Policy detailed below. It comprises three strategic intervention areas and sets targets in line with the guiding policy and strategy documents: (1) supporting value addition, (2) securing market access and (3) improving the investment climate.
National Industrial Policy	The policy promotes the positioning of the Namibian society as a knowledge- and innovation-based society with a competitive and sustainable "green" economy, high employment levels and social justice. Other key principles are macroeconomic stability, openness to enhance free trade as well as equitable and broad-based economic empowerment to ensure that all people benefit from rapid economic development and addressing rural and urban disparities. It places a strong emphasis on "going green" with an emphasis on sustainable manufacturing and development practices.
Poverty Reduction Strategy	Namibia's Poverty Reduction Strategy focuses on three areas that are considered key to progress in poverty reduction. It examines: • How to foster more equitable and efficient delivery of public services (in the context of Namibia's commitment to regional decentralisation) for poverty reduction countrywide. • How to accelerate equitable agricultural expansion, including consideration of food security and other crop development options. • Options for non-agricultural economic empowerment, including an emphasis on the informal sector and self-employment options.
National Agricultural Policy	One of the main objectives of this policy is to increase the contribution of the agriculture sector to national development objectives such as high and sustained economic growth, employment creation, increased income equality and industrial development. This policy establishes "mechanisms to support farmers in combating bush encroachment effectively in both the short and long term". This includes making bush thinning technologies and inputs available at the lowest possible prices; conducting research and offering advisory services to farmers on issues relating to bush control and use; and promoting private-sector and labour-intensive use of bush-based products.

The strategy also aligns with the objectives of the Renewable Energy Policy and the NIRP in encouraging a limited carbon footprint through the development of a bush biomass sector.

Renewable Energy Policy	One of the main goals of the Policy is to encourage value-added activities in Namibia's Renewable Energy Sector. The use of renewable resources should diversify the energy mix and enhance Namibia's resilience to climate change. Renewable resources (solar, wind, or invader bush-based bioenergy) are considered abundant and have a negligible carbon footprint.
National Integrated Resource Plan	The National Integrated Resource Plan (NIRP) is a 20-year development plan for Namibia's electricity supply industry, spanning the period between 2016 and 2035. It provides a projection of Namibia's expected future electricity demand and identifies the mix of resources required to meet the country's electricity needs in an efficient and reliable manner at the lowest reasonable cost. The NIRP has a plan A and a plan B for developing the biomass-to-energy sector. Plan A targets 40 MW generated from biomass by 2030 and 80 MW by 2035. Plan B (more ambitious than Plan A) targets 80 MW by 2025. Biomass is considered as a support resource (as opposed to main resource) in all envisaged scenarios.

Bush resource use is regulated by several legislative instruments within MEFT and other ministries.

- **The Forest Act of 2001 and Forestry Regulations of 2015** define the harvesting and transport permit system, provide for regulation of woody resources use, monitoring and verification of bush-thinned areas and ensure the sustainability of the sector. The use of arboricides through aerial spraying is prohibited. The Forest Act is currently being updated.

- **The Environmental Management Act 7 of 2007** defines activities that require an Environmental Clearance Certificate, which includes bush-based harvesting activities. Synergies with the enforcement of these legislations are key to ensuring a sustainable biomass sector.

- **The Soil Conservation Act of 1969** makes provision for the prevention and control of soil erosion and the protection, improvement and conservation of soil, vegetation and water supply sources and resources.

- **Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act of 1947**: All chemical products used in Namibia must be registered with the registrar of this act. The act makes it possible to prohibit the use or import of any substance that could pose an environmental risk.

- **The Agricultural Pest and Management Act of 1973** aims to prevent the introduction and spreading of plants, insects, non-farming exotic vertebrates as well as diseases that may be detrimental to the agricultural sector. Section 12 permits the import of biological control agents required to control or eradicate weeds and pests.

- **Import and Export Control Act of 1994**: A permit issued under Subsection 1 prescribes the quantity or value of goods that may be imported or exported, their price, the period, the port, the country or territory from or to and the way the goods may be imported or exported. Prohibition can apply to any goods and can be differentiated by origin of the imported good, the destination of the export and the channel through which the good is traded.

- **The Standards Act 18 of 2005** establishes and defines the mandate of the Namibian Standards Institution as the national standards body of Namibia. Standards developed by the NSI must be in line with internationally accepted norms such as the ISO and IEC directives.

- **The Communal Land Reform Bill of 2002** stipulates the mandate for communal land boards and traditional authorities to allocate customary land rights and leaseholds on communal land. The aim of registering land rights in communal areas is to ensure tenure security and promote investments into land.

- **The Agricultural (Commercial) Land Reform Act 6 of 1995** outlines procedures for the acquisition of agricultural land (if under-utilised, excessive, owned by foreigners or offered for sale) by the state. The state has preferent right to purchase agricultural land. In addition, the minister receives the right to expropriate, alienate, lease or dispose of land and defines conditions and procedures.

- **The Labour Act of 2007** creates various institutions responsible for registering job seekers and positions, finding appropriate employment for job seekers, advising on vocational training and many tasks outlined under the mandates created by the act.

- **The Water Resources Management Act of 2015** stipulates that the removal of trees, of riparian growth and vegetation can be prohibited in a declared water protection area.

- **The Local Authorities Act 23 of 1992** stipulates that local authority councils have the power to remove trees to beautify and secure neatness of an area under their authority.

Bush control can contribute to the goals of the policies, conventions and strategies outlined above, if the removal of excess encroacher bush is done within ecological restoration principles without causing other forms of land degradation. This strategy is directly supporting the NRMP&S in providing guidance on bush encroachment management. The strategy sets a new target of **15.5 million ha** for bush thinning and savanna ecosystem rehabilitation efforts aligned with Namibia's Enhanced Nationally Determined Contribution.

Bush control and bush biomass utilisation through all the existing and potential value chains can contribute to improved domestic economic development and add value to export products. Utilising bush biomass is fostering the bio-based economy by creating employment and income, especially in rural areas. It serves as innovation drive for future green technologies. Bush control and the subsequent use of the biomass can contribute to poverty reduction.

4.3 Institutional Arrangements: Roles and Responsibilities

Key mandates for the governance of the sector are assigned to the Ministry of Environment, Forestry and Tourism (MEFT) which is responsible for promoting the rehabilitation of degraded land and land degradation neutrality, as well as promoting sustainable resource management and use. MEFT is the main regulator of harvesting of bush biomass resources.

The Ministry of Industrialisation and Trade (MIT) supports the development of value chains based on these bush resources. The Ministry of Agriculture, Water and Land Reform (MAWLR) plays a significant role in enabling the growth of the sector, promoting sustainable rangeland management to reduce and avoid bush encroachment, as well as ensuring equal benefits to all actors. Figure 6 below highlights the key mandates of the three main government ministries with respect to bush resources and the bush biomass sector.

Other important stakeholders in the implementation of the strategy include, but are not limited to, the Ministry of Mines and Energy (MME), the Ministry of Urban and Rural Development (MURD) and traditional authorities, the Ministry of Labour, Industrial Relations and Employment Creation (MoL), the farmers' unions [Namibia Agricultural Union (NAU), Namibia National Farmers' Union (NNFU), Namibia Emerging Commercial Farmers' Union (NECFU)], Namibian Association of CBNRM Support Organisations (NACSO), the Namibia University of Science and Technology (NUST), the University of Namibia (UNAM), the International University of Management (IUM), representatives of the industry such as the Namibia Charcoal Association (NCA), Namibia Biomass Industry Group (N-BiG), the Agronomic Board, the Meat Board and the Namibia Power Corporation (NamPower), as well as commercial banks, AgriBank and Development Bank of Namibia (DBN). Farmers' unions play an important role in promoting sustainable bush control and spreading awareness on sustainable methods and holistic rangeland management.

Due to the cross-sectoral nature and multitude of stakeholders involved in the management of bush resources, involvement and coordination will be an important component for the implementation of this strategy. A **National Coordinating Body** in the form of a committee is required to ensure collaboration, exchange of knowledge, effective adaptive management and learning for improved decision-making. Preliminary ideas on the initiation of the coordinating committee are detailed in Section 4.4.

Ministry of Environment, Forestry and Tourism

The MEFT is responsible for the sustainable management and use of natural resources in Namibia. As the main regulatory power, it provides guidance on environmentally sound measures, the quantity of resources that can be removed based on the established regulations and permit system and the monitoring of the resource base. The ministry is also the focal point of international conventions that Namibia has signed and thus responsible for their implementation.

Ministry of Industrialisation and Trade

The MIT takes full responsibility for directing Namibia's industrialisation, promoting the development of bush value chains in Namibia for both national markets and export. It oversees the value addition to bush resources, ensuring their quality and finding local and international markets.

Ministry of Agriculture, Water and Land Reform

The MAWLR is repsonsible for land-use planning to optimise and improve land use through appropriate management. Bush encroachment is considered a significant problem on commercial, communal and resettlement farms and is included in land use planning. The ministry has an interest in restoring rangelands and increasing agricultural productivity and thus promoting bush control practices.

Figure 7 *Institutional mandates of the key ministries.*

4.4 Key Priorities

Key priorities identified for the strategy under MEFT mandate which require clarification or guidelines include:

Table 3 *Key priorities for the strategy*

	Sustainable Harvesting and Post-Harvest Treatment: This priority area focuses on permitted practices and tools for harvesting. It also clarifies desirable harvesting systems and objectives for various land-use types and for different tenure categories (commercial, communal and state land) based on research and other regulations. It also addresses the necessity and conditions for post-harvest treatments or aftercare in areas where bush has been thinned. It addresses the risk of deforestation and degradation linked to bush control.
	Improved Resource Monitoring: Improved monitoring is vital to avoid over-harvesting and the associated negative environmental impacts. Guidelines on recording off-takes and a clear inventory of bush resources before and after bush control are presented in addition to innovative approaches based on remote sensing.
	Contribution to Climate Change Adaptation and Mitigation: Namibia is very vulnerable to climate change and climate change adaptation is a priority, while low-carbon development is high on the international agenda. The adaptation and mitigation potential of bush control are presented based on existing literature and demands from international conventions and programmes.
	Contribution to Reversing Land Degradation, Improving Land Productivity and Groundwater Recharge: This priority area discusses the effects of bush encroachment in terms of land degradation and desertification under the umbrella of the UNCCD, and which conditions/precautions are necessary to follow a land degradation neutral pathway.
	Contribution to Enhanced Biodiversity: Based on the UNCBD and NBSAP II, this priority area includes conditions and precautions to ensure the enhancement of biodiversity and connected landscapes.
	Research and Development: Research and development are critical to monitoring the resource base and developing new environmentally conscious technologies adapted to the Namibian context. Research priority areas will be outlined.
	Capacity building, Awareness Raising and Public Dialogue include the use of pilot farms, training for sustainable harvesting practices, communication on regulations and certifications and capacity building within forestry on digital monitoring of resources pre- and post-harvest.
	Resource Mobilisation: A key component of building capacity towards the implementation of this strategy is to secure adequate financing to achieve desired outcomes. Limited access to finance and a lack of resources are key barriers to upscaling of bush thinning and post-harvest treatments. Appropriate financing tools and regulations can incentivise the sustainable management of bush resources and the positive contribution of bush control to restoration and rehabilitation objectives, economic development and human wellbeing.
	Sector Coordination: The governance of bush resources involves a wide range of sectoral and cross-sectoral stakeholders. Ensuring cooperation and bringing all relevant ministries and stakeholders together to navigate the complex and multi-disciplinary problem of bush encroachment and biomass utilisation is a necessity.

Sustainable Harvesting and Post-Harvest Treatments

Bush encroachment has reached a critical point where it compromises the provision of some key ecosystem services in Namibia such as livestock production, groundwater recharge, tourism and biodiversity – important pillars of Namibia's economy (Smit et al. 2015). The key to sustainably managing bush resources is the careful consideration of positive and negative impacts (outlined in Section 1) and the role of bush species in savanna ecosystems. The following section provides guidelines and key considerations for bush control.

Optimum Savanna Ecosystem

The savanna ecosystem can reach an equilibrium or a relative stability in different states:

1. An encroached area with very dense bush is a very stable environment, although at a lower ecological level than its optimum due to its unproductive and degraded state. When bush is removed, a vacuum in the ecosystem is created, reducing the resilience of the ecosystem. This vacuum must be filled. In the short term, this vacuum may be filled by desired grasses, but this hardly ever becomes a permanent state without further management. The proliferation of pioneer species, encouraged by disturbances, often creates a state worse than before, since the removal of bush does not just release competition for the grass layer but also for remaining bushes, which will grow quicker until another equilibrium is reached (Smit et al. 2015).

2. Inter-bush competition in a mixed savanna can lead to another equilibrium, where the establishment of bush seedlings is suppressed by larger bushes (Smit et al. 2015).

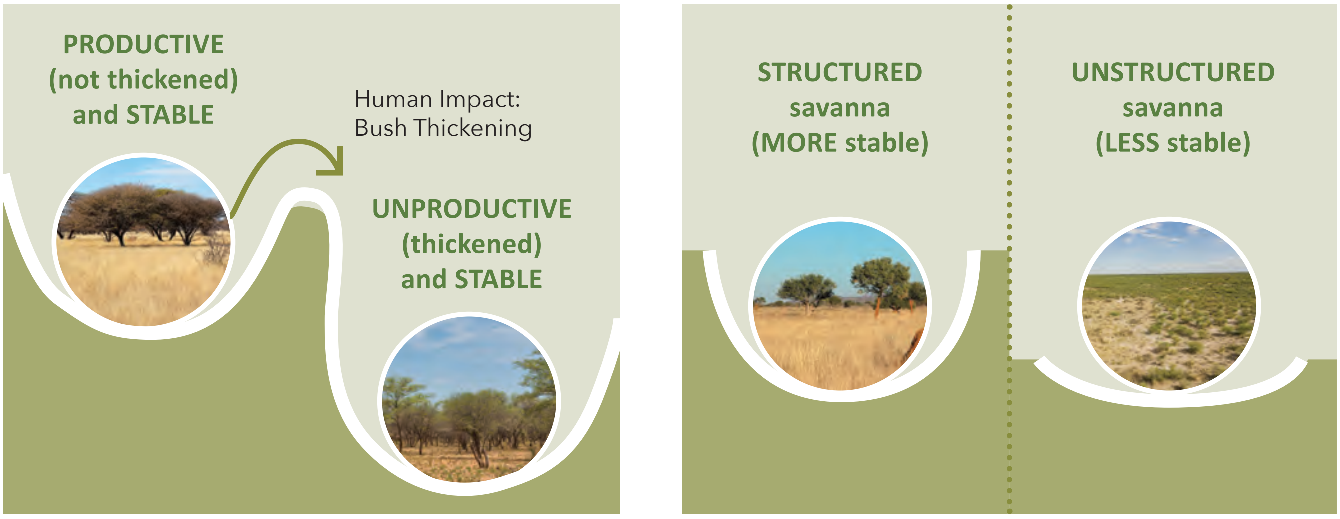


Figure 8 *A simplified model of the competitive impact of preserving large bushes on the stability and resilience of the savanna ecosystem (Smit et al. 2015, Quantifying Harvestable Encroacher Bush).*

As a result, for the responsible thinning of bush to rehabilitate mixed savanna landscapes, selective thinning and leaving larger trees and bushes in the landscape is a necessity.

The desired landscape after bush thinning remains a wooded savanna with a healthy biotope suited to the climate and soils of the area:

An important international concern is deforestation, which is *"The conversion of forest to other land use independently, whether human induced or not".*

Bush resources in Namibia are part of savannas and woodlands (tree and shrub savanna biome) and thus not classified as forest. The complete clearance of land is forbidden unless special permission is given as per the Forest Act to minimise soil disturbance, limit re-encroachment and ensure a positive impact on biodiversity. Only cutting large trees is not considered bush control.

Bush thinning can be implemented for two main objectives: (1) Land Rehabilitation or Restoration and (2) Agroforestry or Bush Farming. **Given the extent of bush encroachment in Namibia, the primary objective is the rehabilitation and/or restoration of degraded land and ecosystems.**

OBJECTIVE 1: Land Rehabilitation or Restoration

If the main objective is rehabilitation (returning the land to a productive state), selective thinning should be used as it is the most environmentally sound.

- Smaller bushes should be harvested first, and the **larger bushes and trees should be maintained.**
- The main objective should be to reduce leaf not woody biomass. The leaf biomass transpires and dictates water use of bush, which stands in direct competition with grasses.
- Maintaining large bushes can contribute to a more stable and productive ecosystem.
- The competitive effect of large bushes on the establishment of smaller bushes can also reduce the frequency and costs of the required post-harvest treatments (Smit et al. 2015).

Definition: Restoration and Rehabilitation

Restoration is *"the process of assisting the recovery of an ecosystem that has been degraded. Restoration seeks to re-establish the pre-existing ecological structure and function, including biotic integrity".*

Rehabilitation is *"actions undertaken with the aim of reinstating ecosystem functionality, where the focus is on provision of goods and services rather than restoration"* (Orr et al. 2017).

OBJECTIVE 2: Agroforestry or Bush Farming

If the main objective is sustainable utilisation, a certain minimum biomass harvesting per hectare may be necessary to make operations economically viable. Larger bushes yield higher biomass and a compromise between leaving some bushes, while maximising harvest, must be found. The decision whether to remove plants or let them regrow for future harvesting should be decided by the individual farmer (Smit et al. 2015), unless an overarching ecosystem-based rehabilitation effort applies, involving several individual farmlands.

There are two main harvesting scenarios for the sustainable use objective:

1. **Pruning or Thinning of Stems and Branches:** Not the entire bush is cut, and only individual branches of a desired size are harvested, leaving the other branches to grow to a desired form. This may require an initial thinning operation to make the land more accessible and encourage the growth of existing bushes.
2. **Felling:** The entire bush is cut above ground after which the bush can regrow.

Further research is required to test these methods and assess the ecological response under local conditions. Decisions by farmers should consider that:

- Most bushes coppice strongly after being cut and new establishment of shoots may be encouraged.
- The structure of bushes is likely to change from single-stemmed to multi-stemmed and will most probably not yield the same biomass as the original plant, since bushes focus on re-establishing leaf biomass. Pruning can reduce this effect. However, early pruning can cause plants to die.
- The species composition may also change from a dominance of high wood potential species to a dominance of more aggressive species (e.g. *Dichrostachys cinerea*, *Grewia* species and *Catophractes alexandri*) with a low wood potential.

Thus, a post-harvest treatment plan should be a vital component for anyone pursuing this objective. It should focus on controlling undesirable species with a low biomass, while pruning desirable bushes to encourage the development of thicker stems with higher biomass yields (Smit et al. 2015). Continuous light thinning may be required to ensure bush farming remains viable.

Integrated Bush Management Systems

Integrated control of bush encroachment should involve various preventive and restorative control measures (outlined in Section 1 and Annex 3). A holistic approach to managing bush encroachment is vital and should include:

1. Interventions to avoid bush encroachment (*where possible*).
2. Interventions that reduce bush densities.
3. Follow-up interventions that prevent re-encroachment.

Due to the stimulated seedling establishment and sapling growth following bush thinning, post-harvest treatments are vital to maintain a desired landscape in the long term. Integrated bush management systems consider the prevention, timing of initial control and follow-up treatments (Archer & Predick 2014, Twidwell & Fogarty 2020). The thickening of woody plants is a continuous process in savannas. Thus, it cannot be controlled by a single bush thinning operation but requires continuous planning and implementation to effectively ensure the stability of the ecosystem. In areas with very high densities, a first drastic thinning measure will be necessary before a post-harvest treatment programme can be implemented (Smit n.d; Lesoli et al. 2013).

Guidelines

- **Understanding the Causes:** The success of bush control depends on the understanding of the causes of bush encroachment and hindrances to the natural recovery of the ecosystem. This involves having a clear objective of the future status of the ecosystem and should consider costs and benefits.

- **Understanding Characteristics of the Ecosystem:** Control and post-harvest measures must consider the characteristics of the ecosystem and the stage of encroachment.

- **Having a Plan for the Desirable State and Appropriate Measures:** Prior to any bush thinning measures a post-harvest or post-thinning plan should be developed and can be included into existing management plans required by the Forest Act or other legislation, regulations, or institutions.

- **Assessing Performance:** The removal of woody plants can leave the land vulnerable to erosion or re-encroachment, independent of the method used. Performance measures should be defined and monitored.

- **Integrated Management:** Adaptive management is a key component for ensuring that status and trends are monitored, and decisions are adapted to create a balance between ecological, economic and social objectives. Bush encroachment in Namibia covers vast areas. Small-scale bush control efforts may be insufficient to contain the expansion of bush. Efforts to control bush encroachment must be spatially explicit, considering encroached areas, seed contaminated areas and intact areas.

Harvesting Methods and Quantities for Land Restoration

Harvestable quantities for the restoration/rehabilitation objective and key guidelines are outlined below. More detailed information on mitigating potential environmental impacts of specific harvest and post-harvest measures is provided in Annex 3.

Based on the Forestry and Environmental Authorisations Process for Bush Harvesting Projects published by the Ministry of Agriculture, Water and Forestry and the Ministry of Environment and Tourism in 2017, the permitted harvesting quantities depend on the dominant species:

Table 4 *Thinning limits for different thickening species*

Lower Limit **Rehabilitation/Restoration Objective**	
Species	**Density Limit**
***Senegalia/Vachellia (Acacia)* Species** (incl. *mellifera, reficiens, luederitzii, erubescens, fleckii and nebrownii*)	Maintain a bush density of BE/ha = **1.5 x** the average annual rainfall. On **sandy** soils: BE/ha = **2 x** the average annual rainfall. Leave trees with a stem diameter **> 18 cm**.
Dichrostachys cinerea	Maintain a bush density of BE/ha = **1.5 x** the average annual rainfall. Leave trees with a stem diameter **> 18 cm** and larger bushes **> 10 cm**. ***D. cinerea*** is a fast-growing species with a short life-span and considerable seed production and is thus a very aggressive encroacher. In areas dominated by this encroacher, it may be necessary to control *D. cinerea* to the above-mentioned density first and maintain other (encroacher) species to enhance competitive controls. Post-harvest treatments are vital.
Terminalia sericea	Maintain a bush density of BE/ha = **3 x** the average annual rainfall. Leave trees with a stem diameter **> 18 cm**.
Colophospermum mopane	Maintain a bush density of BE/ha = **2 x** the average annual rainfall. First assess the field: more may have to be left. Leave trees with a stem diameter **> 18 cm**.
Rhigozum trichotomum	Maintain a bush density of BE/ha **= 2 x** the average annual rainfall.

Upper Limit
A general guideline is that a median ETTE/ha not higher than 10 times the annual rainfall should be maintained. After this, the grass layer may be affected (Smit et al. 2015). As a result, thinning should be conducted once the average ETTE/ha exceeds 10 times the annual rainfall to avoid potential negative impacts on the ecosystem.
A bush equivalent (BE) is a bush of 1.5 m in height: one dwarf shrub of 75 cm in height would be ½ BE, while a large tree of 4.5 m in height would be 3 BE. An evapotranspiration tree equivalent (ETTE) is the leaf volume equivalent of a 1.5 m single-stemmed tree.

While the goal for the restoration objective is to create a spatial mosaic of woody vegetation, bush farming or agroforestry will create a temporal mosaic. The suggested minimum densities and the desired patchy landscape are difficult to apply at a very small scale for the commercial use of bush resources.

A minimum area should be defined or the **Bush Farming / Agroforestry Objective** to mitigate against harmful management practices. Further research and pilots should be conducted. A minimum size is required to make activities economically viable. Farmers in communal or commercial areas could create cooperatives to achieve the minimum scale needed for the sustainable use of the resource. The average density outlined above should be the same but apply to an average farm (e.g. 5 000 ha) to achieve landscape objectives.

Bush control or harvesting should be conducted at or below what can be permanently sustained. According to FSC guidelines, harvestable quantities should be based on a detailed inventory of the resource, which includes quantities, growth, yield and mortality rates, as well as the maintenance of ecosystem functions. For the rehabilitation/restoration objective, the maximum allowable harvest may not exceed the growth rates of specific species (FSC 2020).

Harvesting of all wood resources is regulated by the Forest Act and its regulations as well as the Environmental Management Act and its regulations. The authorisation process for bush control is presented in Figure 8 below:

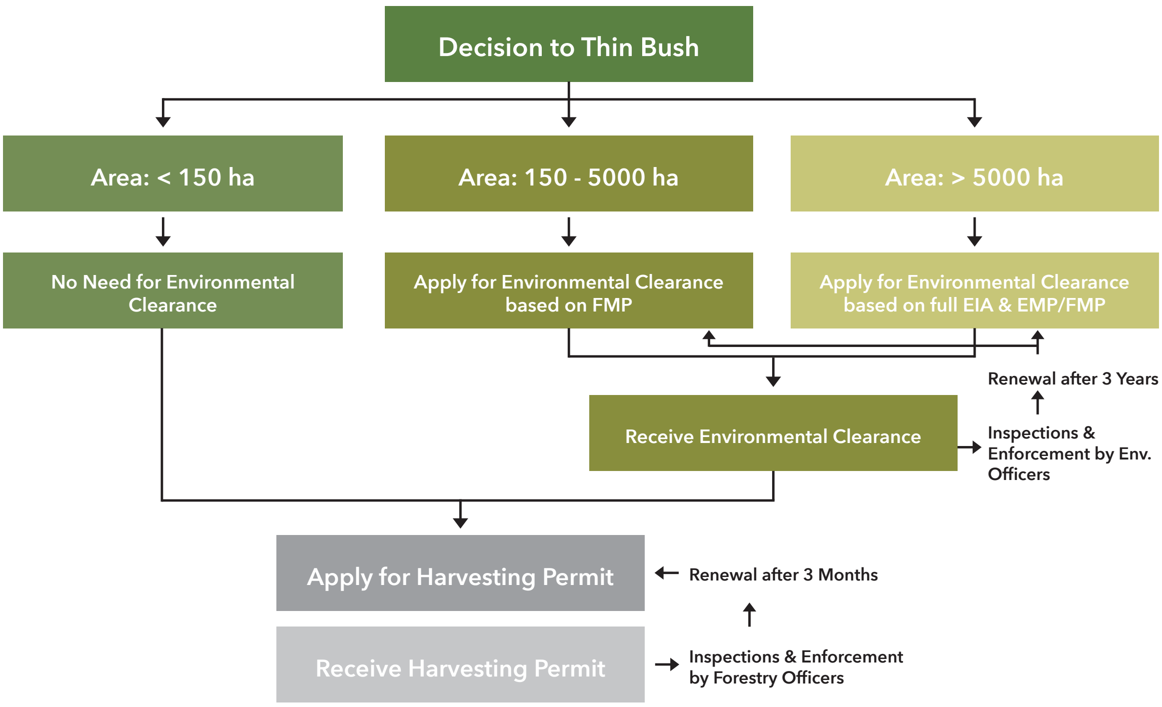


Figure 9 *Authorisation process for bush thinning (based on MAWF & MEFT 2017).*

For every area (including below 150 ha) a harvesting permit and potentially a transport and export permit are required. If bush control is conducted on more than 150 ha, an Environmental Clearance Certificate is required in addition to the harvesting permit (Joubert & Zimmermann 2017).

Guidelines

- **Local Conditions:** The harvestable quantities and the ideal number of bushes that should be left depend on the aridity of an area, its natural vegetation and average long-term rainfall. In wetter areas, more woody biomass can be maintained without affecting the herbaceous layer.
- **Maintaining Protected and Rare Species:** Rare and protected species may not be targeted during thinning activities. Any thinning of protected species (such as Mopane) must be approved by a senior official in the Department of Forestry.
- **Selective Harvesting:** Desirable species should be retained unless special permission is granted. Bush control should focus on potentially problematic species, that may thicken under specific circumstances. The bush should be selectively harvested, leaving the largest plants and targeting smaller bush. Contour harvesting should be promoted to enhance water and nutrient cycling (in line with the density limits in Table 4 above).
- **Maintaining Large Trees:** Trees with a stem diameter of > 18 cm may not be removed.
- **Maintain Diverse Landscapes:** Thickets of bush should be maintained to create patch mosaics. Any plants that are not considered problem species should be maintained. Bush control activities should leave trees and shrubs of different sizes, including some "encroacher species".
- **No Land Clearing:** Total clearing of all bushes should not be permitted due to the negative impact on soil nutrients and thus fertility. Special permission may be given under specific circumstances (e.g. the creation of crop fields).
- **Improving the Soil:** Some dead trees should be left on the land, or some finer branches should be laid out as bush filters. Soil disturbance should be minimised. Using some sort of soil enhancement should be a non-negotiable component of bush control programmes.
- **Securing Waterways:** No bush thinning should be conducted within 100 m of river courses.
- **Planning:** Bush control 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. It should also be integrated into general land-use planning.
- **Grazing Management:** Good grazing management is a vital component to bush control. The grass layer should be growing on the site and land must be at some stage of recovery before grazing livestock. Grazing management must be based on the carrying capacity of the land to prevent further encroachment.
- **Making Informed Decisions and Encouraging Learning:** Trials must be conducted in Namibia to test the effectiveness under local conditions.
- **Fire Management:** Prescribed and controlled fires should be used to control the fuel load and create fire breaks to reduce the risk of uncontrolled wildfires caused by natural hazards and human activities (such as charcoal production).

4.4.1 Sustainable Harvesting in Different Tenure Systems

The main difference between the different tenure types is land ownership, the access to resources and the associated obligations and management considerations.

Commercial Land

The barrier to entry on commercial land is low, as most land users have both ownership over the land and access to the resources. There are large differences between commercial farmers and their approach to bush control: some more ecologically sound, some very harmful. In the absence of thoroughly researched and standardised guidelines, bush control is often conducted based on trial and error. Different methods have different success rates, which are often not adequately recorded.

On commercial land, the ultimate decision on how to manage bush resources lies with the landowner. However, the following key considerations should apply:

- Chemical control and heavy machinery that do not comply with EMP provisions and are harmful to the environment must be avoided, since impacts can have consequences for the ecosystem, not just at farm level.
- Bush control measures should depend on the site conditions and prevalent species. The causes of bush thickening must be identified and addressed to avoid focus on short-term solutions and improve the productivity of the land in the long term.
- Soil enhancement and responsible grazing management should be encouraged since it creates wider benefits.
- Post-harvest treatments should be implemented and adapted to the control methods used. Detailed integrated management plans should be provided if heavy machinery or chemical methods are used.
- Solutions to the financing challenges must be found.

Resettlement and leasehold farms have a different ownership status than fully private commercial land. However, they are managed in a similar manner and should follow the guidelines above.

There is a considerable need for a platform to share experiences across tenure systems. In addition, overarching approaches involving several farms should be considered to increase the effectiveness of interventions.

Communal Land

On communal land, there is no outright barrier to entry, but the land and resource rights need to be obtained. Customary land rights are insufficient to acquire resource rights and communities in communal areas have two main options: registering a community forest or a cooperative, which requires them to have a Forest Management Plan.

Land in the communal areas is a common pool resource. Farmers conducting bush control, which requires considerable labour and financial resources to improve the land will share these benefits with all other farmers. This disincentivises investments into improving the condition of the land (De Klerk 2004). At the same time, households in the communal areas depend on woody resources for their energy needs. Where large-scale commercial harvesting in communal areas is introduced, household demand for wood resources must be considered to avoid competition.

Key challenges of bush control and the subsequent utilisation of the resource are issues around sustainable resource use, inclusivity, and equitable benefit sharing. Existing structures such as CBOs, PPOs or cooperatives should coordinate efforts and ensure the distribution of benefits. They are also responsible for monitoring and enforcement. Responsible entities for bush management can include management committees of communal conservancies, community forests, as well as management committees of other classified forests (incl. state and regional forest reserves and forest management areas).

Bush control and sustainable use of bush biomass in communal areas requires a specific framework that must be piloted.

To create employment, selective manual to semi-mechanised harvesting should be promoted. There should be limitations to the amount that can be removed to avoid overexploitation, diligent monitoring, and enforcement of rules. When bush control in communal areas is conducted, harvesters should have a responsibility to give back to the land, for example by conducting some soil enhancement like brush packing, which is cost-effective and easily accepted by local communities as it does not require additional inputs (Sebitloane et al. n.d.).

Protected Areas

In protected areas, the barriers to entry are the highest.

The presence of wild browsers and grazers should be enough to maintain a stable ecosystem and avoid bush encroachment – especially if large numbers of elephants are present. In addition, most protected areas have a fire management plan and controlled burning, which should reduce the need for more drastic measures.

The use of heavy machinery and chemicals in protected areas should be forbidden due to the potential harmful impacts on ecological processes and the disturbance to wildlife.

If bush thickening cannot be controlled with fire, natural browsers and grazers, some very selective and conservative harvesting with manual methods could be used to support natural fire and biological processes. Removed biomass should remain on the land to be used for soil enhancement purposes, except if the economic potential considerably outweighs the ecological benefits.

Bush control should be conducted by the relevant National Parks authorities, who are knowledgeable of the area and species.

Urban Areas

Bush control in urban areas will depend on whether it is conducted on private property or the property of state/municipality. Harvesting of bush resources in urban areas is overseen by municipal authorities as per the Local Authorities Act of 1992. Local by-laws and zonation may also apply.

Urban planning should accommodate green spaces. Generally, selective thinning should be promoted to maintain native vegetation. However, there may be a need for more drastic measures. The use of chemicals should not be allowed due to the high population density and potential harmful impacts through spray drift and leaching.

Post-harvest treatments may be necessary to avoid the establishment of other problem plants, for example different cactuses that are already a problem in larger towns.

More research is required on the state of bush encroachment in urban areas and current practices.

4.4.2 Improved Resource Monitoring

Monitoring includes both the long-term monitoring of environmental and socio-economic impacts of bush control, as well as inspections conducted by trained personnel to assess the adherence to regulations and permitting requirements.

Monitoring should be a key part of a management system and provides the basis for sound decision-making. It gives an early indication of potential risks and threats. Corrective and cost-efficient actions can be taken. It also helps to evaluate the performance of different management measures (De Klerk 2004) and allows for adaptation and learning. To effectively monitor socio-economic indicators, gender-disaggregated data should be collected where possible.

In addition, resource monitoring is key to ensure that bush control is conducted in a responsible manner and that key regulations to avoid the overexploitation of resources as well as the conservation of protected species and large trees are adhered to.

Monitoring of bush resources should be conducted by:

- **Government:** The Directorate of Forestry within the Ministry of Environment, Forestry and Tourism is responsible for monitoring the resource and enforcing regulations on the sustainable use of forest resources. They require good knowledge to make decisions and provide well-informed extension services to resource users.
- **Landowners and Land Users:** Monitoring at farm level and community level should be conducted for informed management decisions and to facilitate adaptive management. This can include the collection of data on livestock and wildlife numbers, fires, rainfall, frost events, the amount of bush, seedling densities and grass density among many others. Land users can be supported by extension services when it comes to the analysis of the data (De Klerk 2004).
- **Civil Society Organisations and Academia:** Organisations such as researchers, farmers' associations, industry associations and NGOs can contribute to coordinating monitoring and evaluation efforts and supporting the implementation of monitoring activities (*ibid*) –especially for self-monitoring systems.
- **Accreditation or Certification Bodies:** Accreditation bodies, such as the FSC, conduct regular monitoring to ensure standards are adhered to.

Different Monitoring Methods

Remote Sensing and GIS

Remote sensing and GIS allow for the analysis of long-term trends and identifying drivers of change and changes in land cover over time. Monitoring using satellite data can be critical for planning and management when detailed cartographic information is lacking (Wingate et al. 2016).

Satellite remote sensing of woodland vegetation can be difficult due to the mixed tree and grass strata with considerable inter- and intra-annual changes in biophysical properties. It can provide valuable insights if a multi-sensor strategy is used (Wingate et al. n.d.) or if it is complemented by other methods. Low-resolution satellite sensors often have a complete geographic coverage and collect data daily, which allows for detailed evaluations of changes in vegetation conditions over time. The most frequently applied index to monitor biomass resources is the Normalised Difference Vegetation Index (NDVI). It is the simplest way to estimate biomass production since it is linked to photosynthetic activity (Espach et al. 2006). It can help to identify bush encroachment hotspots and sites where specific preconditions make bush encroachment likely (Graw et al. 2016). It can also contribute to evaluating the land cover after bush control. Downsides of remote sensing are that you cannot distinguish between species and the height of trees. However, it can be useful if triangulated with other field methods and drones.

LiDAR stands for "Light Detection and Ranging". This remote sensing technique uses laser scanners to create three-dimensional models by emitting light pulses and timing their reflections from targets to create point clouds (Marselis et al. 2015). LiDAR allows for height determination of woody vegetation. Various types of scanners are available:

- **Terrestrial-Based LiDAR (TLS)** creates very detailed data on mid- and under-storey vegetation including the tree stems and diameter. They are mounted on a tripod and thus only collect data for a limited area around the device. Mapping large areas can be a tedious process (*ibid*).
- **Hand-Held LiDAR** allows for rapidly collecting data, creating huge opportunities for research and monitoring. They are very cost-effective and provide detailed information on the understorey. They are thus very useful for repeat surveys or monitoring purposes (*ibid*).
- **Aerial Surveys** are often more spatially comprehensive and cover a larger area. Since they mainly provide data on the canopy tops, they can be merged with TLS data to create a more complete picture (*ibid*).
- **Unmanned Aerial Vehicle (UAV) - Mounted LiDAR** using drones, for example, are developing rapidly and provide high spatial resolution and temporal datasets. They can collect data on the location, height, and canopy width of trees. However, in terms of assessing understorey plants they have similar drawbacks to other airborne data – although the point density can reduce mapping errors (*ibid*).

Aerial photographs periodically (De Klerk 2004) taken at a national level are often at a higher resolution than satellites and can be analysed with GIS to look at changes in bush cover over time.

Point Sampling

Point sampling is commonly used to estimate biomass cover for rangeland monitoring and inventories. It is a fast and accurate way to determine the botanical composition and state of grasses. It involves systematic point readings taken along transects, which can include density of bushes and grasses, forage height, palatability and species composition (Espach et al. 2006). Conducted at regular intervals, it can provide vital information on the development of the resource and the performance of the management system. Permanent sample plots or fixed sample points can be used to take regular measurements and determine regeneration and growth. Ideally, point sampling should be conducted by the Directorate of Forestry every five years in a consistent manner.

Fixed-point photography can also be used by officials and farmers to analyse changes over time and ensure large trees or protected species have not been removed. However, they are difficult to quantify and can only be used for qualitative assessments.

A detailed inventory of woodland resources should be conducted every five to 10 years depending on the intensity of resource use. If the harvesting intensity is high, inventories should be done more frequently – at least every five years.

Bush Information System

The Bush Information System (BIS) is an open-source platform hosted by the Namibia Statistics Agency quantifying and mapping bush encroachment and the biomass potential across Namibia. The information on the current state of bush encroachment and the development of woody plants was derived from existing information, earth observation data and ground truthing and provides information on woody biomass yield, canopy cover, bush equivalents and changes in woody cover between 2015 and 2018. The information can be used by the government to make decisions, by harvesters to assess suitable areas for harvesting operations and by farmers for spatial assessments of bush density for potential thinning.

Biomass Quantification Tool

As part of the BCBU Project, a biomass quantification tool was developed by J.M. Boys (MAWLR-DARD) and G.N. Smit (University of the Free State). The biomass quantification tool is a standardised, easy-to-use Excel-based model that can estimate wood biomass in a specific area. Initially the tool was developed for specific species including *Vachellia reficiens*, *V. luderitzii* and *Senegalia mellifera*. General regression equations were developed to cater for other species while specific regression equations will be developed for more species over time. The model provides estimates of wood and bush feed dry mass yield (kg/ha), woody plant density (ETTE/ha, TE/ha, and plants/ha). It can also estimate wood dry mass yield when planning to thin up to a pre-determined density (ETTE/ha and TE/ha) (Boys & Smit 2020). It is a self-assessment and self-monitoring tool for farmers.

Inspections

Physical inspections should be conducted by forestry officials before issuing permits and after harvesting took place. Additional inspections can be done by different accreditation bodies.

The use of drones can also offer a cost-effective solution to inspecting sites and assessing whether regulations are adhered to. High-resolution photos taken by drones can be reviewed multiple times and archived to assess future changes (Global Infrastructure Hub 2020).

GPS could be used to record protected species or large trees that should be maintained and for monitoring purposes to assist in the verification process.

Citizen Science and Self-Monitoring

Since monitoring of bush resources can be a very cumbersome process requiring considerable human resources, self-monitoring of woodland resources by farmers, conservancies, community forests and grazing committees should be promoted – acting like an event book system for woodland resources.

Various technical tools to promote citizen science or self-monitoring have been developed but focus on fauna (e.g. SMART). In the USA, Jeff Herrick developed the Land Potential Knowledge System, which is an app-based cloud computing and storage programme to determine sustainable land use based on user inputs, databases and algorithms. The app can be used for rangeland monitoring and assessment, on-farm research and soil health monitoring – amongst many other indicators. He is collaborating with UNAM and the programme was trialled in Namibia (Herrick 2018). The potential inclusion of more bush-related parameters should be investigated.

Database and Analysis

The collection and analysis of data is vital for good science, verification purposes, assessing changes over time and evaluating the performance of different management interventions. Good information provides the basis for adaptive management and sustainability. The data should be open access and accessible to all.

Guidelines

- **Information Sharing:** Collaborative and coordinated monitoring across sectors and at different levels is important to ensure learning, adaptive management, knowledge sharing and to overcome capacity limitations.
- **Transparency:** Ensuring access to information on and experiences with different bush management regimes is vital to ensuring sustainable management of the resource in the long term and making decisions based on the best available knowledge.
- **Embracing Multi-Stakeholder Monitoring:** Citizen science and monitoring by third parties can be a valuable contribution to existing monitoring efforts and should be promoted.

4.4.3 Contribution to Climate Change Adaptation and Mitigation

Climate Change Mitigation

"Activities that aim to reduce Greenhouse Gas (GHG) emissions directly or indirectly (e.g. by changing behavioural patterns, or by developing and diffusing relevant technologies), by capturing GHGs before they are emitted to the atmosphere or sequestering GHGs already in the atmosphere by enhancing their sinks" (IPCC 2019).

The last National Greenhouse Gas Inventory Report published in 2020 (MEFT 2020a) classified woodlands into three main categories:

1. Woodlands where the tree height is higher than five metres and the canopy cover lies between 10% and 20%,
2. Shrublands with trees and saplings that have thickened a long time ago, and
3. Savanna grasslands in which bush thickening is currently occurring, increasing woody biomass.

There is considerable debate around the carbon balance of bush control. The removal of bush will cause the carbon stored in the biomass to be released into the atmosphere contributing to global GHG budgets. However, the impact on soil organic carbon is uncertain and studies confirming increases and decreases in soil organic carbon are available. Some authors who suggest SOC is higher in encroached areas acknowledge that the carbon is not protected and thus more unstable (Boutton et al. 2009, Filley et al. 2013). Grass regrowth after bush control tends to have a positive impact on soil organic carbon (Wigley et al. 2020).

A GHG assessment conducted for Namibia and Namibia's Nationally Determined Contribution assume a positive impact on soil organic carbon, which is in line with studies by February et al. 2013, Hudak et al. 2003, Jackson et al. 2002 and February 2020. The Namibian study suggests that encroached bushland in Namibia stores around 14.5 tons of carbon per hectare on average. In addition, 17.1 tons of carbon per hectare are stored as soil organic matter. In bush-thickened areas, soil organic carbon decomposes over time and more carbon is stored in biomass. Typical savanna ecosystems not affected by bush encroachment store a similar amount of carbon (34.2 t C/ha), although the allocation differs: carbon is mainly stored in the form of soil organic carbon doubling the amount stored in biomass (around 10.9 t C/ha in biomass and 23.3 t C/ha in soil organic carbon). It is suggested that the total carbon stock is slightly higher in a natural savanna ecosystem than in bush encroached areas. Once bush encroachment areas reach an equilibrium, changes in the carbon stored are mainly driven by encroachment into other areas (Seebauer et al. 2019, February et al. 2013, Hudak et al. 2003, Jackson et al. 2002, February 2020.).

A detailed study with soil measurements in different areas and under different bush management regimes should be conducted to assess the impact of bush control on soil organic carbon and inform the promotion of measures that enhance carbon sequestration.

Climate Change Adaptation

"Adjustments in human and natural systems, in response to actual or expected climate stimuli or their effects that moderate harm or exploit beneficial opportunities" (IPCC 2019).

Although the mitigation potential is questionable in the absence of a local study, the adaptation potential of bush control can be considerable: Namibia's is a net carbon sink (MEFT 2020b) but expected to be among the countries most heavily impacted by climate change (Couldrey & Turpie 2020).

Namibia's Nationally Determined Contribution identifies adaptation as an unconditional part of the national development system to enhance resilience. Among the adaptation actions is the restoration of the savanna through bush thinning for increased land productivity, improved food security, improved groundwater recharge and increased biodiversity, as well as bush biomass utilisation and value addition (MEFT 2021).

Adaptation to climate change is a priority in Namibia and bush control is an important adaptation strategy against climate change by increasing the water-use efficiency of the land, reducing the vulnerability to droughts and improving the soil for improved land productivity for diverse land uses.

Adaptation Benefits of Bush Control

Soil cover and plant diversity indicate good soil health, due to the positive impact of diversity on soil microbes, which increases available nutrients and contributes to a more productive and resilient ecosystem. Bush encroachment provides enough organic inputs but can affect soil microbial communities. Decreases in decomposition ratios can impact soil organic carbon and soil fertility (Nott et al. 2019, Buyer et al. 2016), which can be addressed with appropriately designed bush control programmes. The direct competition for moisture between bush and desirable forage can also have a negative impact on the soil.

Under climate change conditions, atmospheric CO_2 increases while precipitation is expected to decrease and become more erratic with spatial patterns changing. This could have considerable impacts on the ecosystems in an already arid country. The increasing CO_2 levels and aridity favours trees over grasses, due to their ability to access water at lower levels (Archer et al. 2017, O'Connor et al. 2014). Bush also intercepts a considerable amount of rainfall using approximately seven times more water than desired grasses. As a result, the water-use efficiency of the land is considerably reduced, making the land even more vulnerable to droughts. Underground water budgets may also be impacted due to reduced infiltration and increased runoff (De Klerk 2004). Bush control can have a positive impact on water budgets and water availability under increasingly arid and variable conditions.

Bush control and the subsequent use of the biomass can contribute to rural income and the diversification of livelihoods. Specific components of the bush can be used for different value chains. Some of these value chains, e.g. bush-based animal fodder, can contribute to drought resistance of agricultural production and enhance resilience of agricultural communities.

Guidelines

- **Improving Soil Organic Carbon:** Soil organic carbon is an important indicator of soil fertility. It can be enhanced by leaving biomass on the soil (e.g. brush packing), minimum soil disturbance, enhancing the activity and diversity of soil fauna, reseeding and good grazing management.
- **Good Grazing Management:** Well-managed grazing can have positive effects on nutrient cycles, water holding capacity, enhanced biodiversity, the oxidisation of methane and soil carbon sequestration.
- **No Clear Cutting:** Bare soil has a negative impact on soil health and carbon sequestration. Living plants are important for soil microbes, a well-structured topsoil, good water holding capacity and nutrient levels.
- **Reseeding:** Reseeding or planting desired fodder bushes can enhance species diversity, forage and grazing for wildlife and livestock and enhance sequestration and soil organic carbon.
- **Minimum Soil Disturbance:** Heavily disturbed, exposed, and eroded soils can lead to the breakdown of soil aggregates releasing soil organic carbon as CO_2. Soil disturbance can also have a negative effect on mycorrhizal fungi, which are vital for long-term carbon sequestration.

4.4.4 Contribution to Reversing Land Degradation, Improving Land Productivity and Groundwater Recharge

Definition: Land Degradation and Desertification

Land Degradation means "reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as:

- soil erosion caused by wind and/or water,
- deterioration of the physical, chemical, and biological or economic properties of soil, and
- long-term loss of natural vegetation" (UNCCD).

Desertification means "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" (UNCCD).

Land degradation is a serious problem in Namibia and three main types of degradation are prevalent: vegetation degradation (includes rangeland and woodland degradation, as well as deforestation), soil degradation and water degradation. Bush-encroached areas are considered key landscapes under Namibia's Third Programme to the UNCCD. The resulting declines in carrying capacity are estimated at up to 100% and more, contributing to considerable economic losses (MET 2014b).

Key indicators of desertification and land degradation include:

- Lowering of groundwater tables
- Soil erosion
- Loss of woody vegetation/trees
- Loss of grasses and shrubs
- Declines in desired grasses and shrubs
- Increasing salt content in the soil
- Decreased soil fertility (De Klerk 2004)

In Namibia, bush encroachment is considered a component of the desertification process as it occurs at the expense of desirable shrubs and grasses reducing land productivity (De Klerk 2004). Land degradation and desertification are driven by inappropriate land uses and agricultural practices, and exacerbated by issues around poverty, population pressure, land tenure, unsustainable use of water resources, inadequate institutional capacity, limited cross-sectoral collaboration, climate change and inadequate application of technology (MET 2014b).

Namibia is dependent on groundwater for water supply to provide drinking water for people, livestock and game, crop production and to supply mines (Christelis & Struckmeier 2011). Bush encroachment can considerably impact the water budget in Namibia by reducing evapotranspiration, soil moisture, infiltration and deep percolation, which contribute to groundwater recharge. Severe bush encroachment can reduce the probability of groundwater recharge to one third when compared to bush-thinned or non-encroached areas (Groengoeft et al. 2018). Bush thinning on 15.8 million ha could lead to N$76 billion of benefits to the Namibian economy over 25 years: N$51.6 billion of these benefits are from increased groundwater recharge (Birch et al. 2015).

Bush control efforts should contribute to improving the productivity of land. Land productivity within the scope of this strategy is considered as a holistic principle as outlined below.

Land Productivity

Bush control should contribute to land productivity and thus

- **Individual Benefits:** Contribute to the wellbeing and economic prosperity of land users through the sustainable use of the resource base and the benefits of rehabilitating the land (e.g. increasing carrying capacity for wildlife and livestock).
- **Benefits to Society:** Contribute to sustainable food systems by enhancing economic, environmental and social benefits (provisioning benefits).
- **Maintenance of Ecosystem Services:** Contribute to important regulatory and cultural ecosystem services such as carbon sequestration, enhanced biodiversity, reduced erosion and aesthetic appreciation – among others.

To improve land productivity, degraded land must be rehabilitated or restored. Bush control can contribute significantly to restoring or rehabilitating degraded land. Measures must be put in place to avoid adverse impacts on the environment through the application of unsustainable bush control methods. To restore and rehabilitate land through bush thinning, some key considerations should be acknowledged:

Guidelines

- **No Clear Cutting:** Clear cutting land and creating bare patches can contribute to desertification and must be avoided. Trees and bushes play an important role in nutrient cycling, enhancing soil fertility, stabilising soils and other vital ecological processes.
- **Post-Harvest Treatments:** Bush-controlled areas often show an increase in problem bush numbers, due to considerable regrowth and coppicing, and post-harvest treatments are vital to not threaten land productivity in the long term.
- **Improvement of the Land:** Soil-enhancing practices and sustainable grazing management are vital components of rehabilitating degraded land. Brush packing, the use of bush filters and reseeding can reduce erosion, in addition to trapping nutrients and increasing soil carbon.
- **Integrated Land and Water Management:** Bush control programmes should consider the potential positive impacts on groundwater recharge. Bush thinning around aquifers or key catchment areas and the impact on water budgets should be explored and promoted.

4.4.5 Contribution to Enhanced Biodiversity

Drought and desertification drive biodiversity loss, which is further exacerbated by climate change, increasing the threat to ecosystems and species diversity. Unsustainable land management is a key threat to biodiversity and leads to land degradation, bush encroachment and soil erosion. As a result, Namibia's National Biodiversity Strategy and Action Plan (NBSAP II) under the UNCBD covers the restoration of degraded land linking it to the UNCCD. Bush encroached land is considered the most serious type of degradation in Namibia (MET 2014a).

Positive	Negative
Trees can have a positive impact by enriching the soil under their canopy. Some desirable grasses are positively associated with tree canopies and they provide an important sub-habitat for different species (Smit 2005). Bush creates unique and diverse habitats and provides browse for livestock and wildlife (Smit 2004).	Bush encroachment can be transformative and change landscapes. This can endanger specific ecosystems and species adapted to these ecosystems and may displace species endemic to savanna or grassland ecosystems (Archer et al. 2017). Woody encroachment can create monocultures decreasing the overall diversity of plant species (*ibid*). There can be an impact on functional groups, species abundance and evenness of the herbaceous layer even if there are no clear changes in species richness (ibid). Changes in the species composition of vegetation can have considerable impacts on ecosystem processes including trophic pyramids, primary production and nutrient cycling (*ibid*). Changes in vegetation can reduce the quality and quantity of habitats for wildlife (*ibid*).

Figure 10 *Positive and negative impacts of bush encroachment on biodiversity.*

Biodiversity should be a key component of land management plans and consider impacts at a system level, e.g. an individual farm or ecosystem. Key biodiversity indicators that should be included into management plans and planning of bush control operations (De Klerk 2004) include:

- Vertical heterogeneity
- Horizontal heterogeneity
- Habitat diversity
- Diversity and abundance of woody species
- Diversity and abundance of perennial grasses
- Animal species richness and abundance
- Conservation status of species
- Trends in alien invasive species

Guidelines

- **Selective Thinning:** Clear cutting the land creates a homogenous landscape and reduces diversity. Selective thinning provides more favourable sub-habitats, increasing the diversity of grass species and animals. Open savanna landscapes with islands of dense thickets may have the highest overall biodiversity.

- **Maintenance of Habitat Heterogeneity:** Bush control is likely to shift species composition from browsers or species that prefer dense cover to other species. Dense patches of bush should be maintained to cater for these species to avoid population decline. The habitat after bush control should remain heterogeneous, with smaller and larger bushes to provide habitat for different species.

- **Consideration of Biodiversity in Planning:** If fire is used to control bush, the area must be sufficiently large to minimise grazing pressure when grasses flush, but small, controlled and slow enough to allow wildlife to find refuge in other areas.

- **No Unselective Use of Chemicals and Mechanical Control:** The broadcasting of chemicals is not allowed due to the non-selective effect on vegetation and to minimise harmful impacts on biodiversity.

4.4.6 Research and Development

Research is vital to ensure that decisions are based on good knowledge and understanding of the ecosystems and key issues at stake. Although considerable research on bush resources has been conducted in Namibia, research gaps remain and must be addressed.

The Directorate of Forestry within the Ministry of Environment, Forestry and Tourism (MEFT) is responsible for conducting and guiding research activities. Collaboration and coordination of research activities with academic institutions and civil society is vital to ensure knowledge is shared and key research priorities are addressed. Some key priorities for research are presented below:

Table 5 *Research priority areas and themes on the sustainable management and use of bush resources*

Priority Area	Themes
Understanding Bush Thickening	Carbon stocks and the distribution of carbon in bush encroached and mixed savanna landscapes. Effect of different land uses on vegetation structure and changes.
Environmental Impact of Bush Thinning	Competitive effect and benefits of selective thinning. Impact of different harvesting measures on regrowth of different species. Positive and negative impacts at the ecosystem level of different harvesting and post-harvest treatment measures on different aspects of the environment. The impact of different encroacher species and encroachment densities on water budgets. Continuous monitoring of groundwater recharge and levels for different levels of bush encroachment, vegetation composition and management regimes.
Innovative Bush Thinning and Post-Harvest Treatment Measures	Investigate potential use of biocontrol agents such as insects and fungi in Namibia. Measures to improve soil and land productivity. New and innovative technologies adapted to harvesting Namibia's high-density hardwood bushes. Effectiveness of different measures. What combinations are best to restore degraded land and ensure the maintenance of a desired ecosystem state? Investigate the use of controlled fires to control bush densities and limit seed dispersal. Investigate new technologies and the use of higher resolution images to monitor bush encroachment.
Sustainable Use of Bush Resources	Potential environmental impacts and carbon sink effects of different value chains. Risk assessment of different value chains and development of key mitigation strategies (e.g. risk of uncontrolled fires). Conduct pilot studies in communal areas to test bush control and biomass utilisation models for communal areas with a clear benefit sharing structure.

Guidelines

- **Collaboration** to set priorities for research and coordinate research activities is vital to improve decision-making in the long term. Creating a platform between policy and science is an important component of improved collaboration.
- **Securing Finance:** Ensuring that sufficient funds are available for priority research areas is a necessity. Different financing sources and opportunities must be explored.

4.4.7 Capacity building, Awareness Raising and Public Dialogue

Building capacity at all levels and providing guidelines and information on the sustainable management of bush resources is vital to ensure positive impacts of bush control and mitigate risk associated with unsustainable practices.

Extension Services: Extension services are crucial to ensure that bush control is conducted in a way that encourages long-term sustainable resource management. A training programme should be developed for extension officers to explain the intricacies of bush thinning for restoration. It is vital to ensure that they have the theoretical knowledge and technical skills to advise farmers (De Klerk 2004) and relevant government officials. Extension services should also include awareness campaigns on correct harvesting and bush management techniques.

Information Material and Training on the benefits of holistic management should be widely communicated and distributed to farmers. **Demonstration farms** – that have been identified as best practice – could be used for training during field days. **Exchange visits** between and within different land tenure types could be conducted to enhance knowledge transfer and promote local solutions adapted to differences in intensity and access to capital.

Guidelines

- **Collecting Information:** Information from pilots on bush control and biomass utilisation models in communal areas should be collected, aggregated, and disseminated.
- **Collaboration and Coordination:** A coordinating platform for information sharing between different actors of the bush resources sector can encourage the exchange of knowledge and best practices, coordinate activities and research, and develop appropriate information systems.

4.4.8 Resource Mobilisation

It was estimated that about N$1 billion would be necessary to implement the strategy over the next five years. These resources will provide the necessary technical assistance to establish an enabling environment for sustainable and inclusive harvesting and restoration practices, maximising environmental and social benefits. This financial target represents approximately 10% of the costs for restoring 15.5 million hectares. These estimated costs do not consider costs for ministerial operation or administration of these activities and extensive research projects.

Limited access to finance and lack of resources are key barriers to upscaling of bush thinning and especially post-harvest treatments in Namibia. Currently the private costs and benefits of bush thinning can create distorted incentives towards the use of unsustainable practices. Inadequate funding can be a considerable constraint to the sustainable management of bush resources. Appropriate financing tools and regulations could, however, incentivise the sustainable management of bush resources and the positive contribution of bush thinning to restoration and rehabilitation objectives, as well as economic development and human wellbeing.

Addressing bush encroachment and its socio-economic and environmental impacts is a key priority of the Namibian government and relevant ministries. The implementation costs should be reflected in the national and ministerial budgets for the next five years and beyond.

However, ensuring the restoration or rehabilitation of bush-thickened land and the sustainable use of natural resources cannot be achieved with public finance alone and should rely on diverse funding sources ranging from public finance, donor finance and conservation funds to private finance.

Some key finance mechanisms apart from government budgets and private sector investment which could be considered include[1]:

Payments for Ecosystem Services (PES) are direct or indirect payments by a user or beneficiary of an ecosystem service to the provider of the service ("beneficiary pays principle"), whose land-use decisions affect these services: The provider of the service is paid for the maintenance and preservation of these services (UNDP 2016a).

The landscape rehabilitation and biodiversity benefits associated with bush management benefit a broader group of people at a local, national and even global level. Payments for ecosystem services have been developed to incentivise the maintenance or improvement of these public goods and services by the people living within the ecosystem, who bare most of the costs of maintenance.

[1] The list of finance mechanism is taken from the "Finance Mechanism Review for Post-Harvest Treatment Measures" prepared by the Juliette Perche and Mirja Stoldt (NNF) for the MEFT / GIZ BMCC II project.

PES schemes around bush management could pay for the use of more environmentally friendly thinning and post-harvest measures (e.g. biological control), for restoring ecosystem services or keeping large trees in the landscape (input-based payments). This could encourage a modification of behaviour to more sustainable practices. An example of output-based payments would be a consortium of tourism companies investing into a fund to finance thinning and post-harvest treatment programmes in areas with high tourism potential to maintain a desired landscape for aesthetic reasons. Another option would be the use of wildlife credits. Tourism operators could pay for increasing wildlife in a specific area by keeping the landscape open and diverse. This would mainly be an option for communal areas. The Forest Stewardship Scheme in Namibia is trying to integrate a subsidy component for ecosystem services provided by farmers who engage into restorative practices. Although the details of implementation are not yet established, this subsidy scheme could be seen as a form of PES mechanism.

Compensation offsets are compliance-related instruments to compensate for activities that will have an impact on the environment. This includes both regulations, enforcement along a mitigation hierarchy and different offset strategies to reach a "net positive impact" (NPI) or "no net loss" (Meyers et al. 2020).

Biodiversity offsets are explicitly linked to specific projects causing a loss of biodiversity and are expected to fully compensate for negative residual impacts. It must be ensured that the "net gain" or "no net loss" is measurable, long-term and an addition to other ongoing conservation measures (World Bank Group 2016).

Biodiversity offsets within the framework of bush management could involve large extractive industries such as mining operators to buy biodiversity offsets from neighbouring farms which conduct sustainable bush thinning and appropriate post-harvesting measures. The offsets' proceeds could then be earmarked for investments in post-harvesting treatments or monitoring. At this stage, only bilateral agreements between private sector and custodians would be viable in the absence of a market for biodiversity offsets, if the biodiversity benefits can be proven and quantified.

Preferential loans are loans provided at an interest rate significantly below the current market rate. Guarantees refer to institutions (or private agents) committing to assume debt obligations if the borrower fails to pay back. A common guaranteed mechanism is a government-guaranteed loan.

These credit enhancement tools can blend private and philanthropic or public funding, substantially reducing perceived investment risks, but also incentivising investment in activities with positive environmental impacts.

To incentivise the sustainable management and use of bush resources, a preferential interest rate could be given to lenders with a post-harvest treatment plan. This could justify the initial investment in bush thinning and ensure a desirable state is maintained in the long term. This would, however, require government warranty or a donor to lower the interest rates.

The **Land Degradation Neutrality Fund** is an impact investment fund using public, private and philanthropic resources to support land restoration and sustainable land management projects implemented by the private sector (UNCCD n.d.).

Currently, the land degradation neutrality market – still in its infancy – mainly consists of sustainable use investments and land rehabilitation (Maillard & Cheung 2016) supporting projects in sustainable agriculture, sustainable forestry and agroforestry as well as sustainable livestock management. Projects applying for funds should create socio-economic and environmental benefits as well as financial returns (UNCCD n.d.).

Bush thinning and post-harvest treatment measures targeting the restoration of mixed savannas in Namibia are exactly within the eligibility of the fund criteria of investment. The fund could provide loans and equities into bush utilisation projects with specific conditions and support for restoration targets. Further information can be accessed at: www.idhsustainabletrade.com/landscapes/ldn-taf/.

Taxes are payments where the distribution is not proportional to payments. The main aim is to increase the costs of activities that may damage the environment and thus incentivise stakeholders to reduce these activities.

Imposing taxes combines the objectives of creating revenue and influencing incentives. They can be targeted to have a desirable impact, e.g. a pollution tax to reduce pollution (Meyers et al. 2020). Increases in VAT for products considered harmful for the environment and biodiversity could be used to disincentivise specific measures. However, this might further disincentivise farmers to take any kind of measures to address bush thickening. A specific environmental tax on beef meat production could also generate funds to reinvest into sustainable land management and integrated bush management support services.

Levies or fees are obligatory payments mostly to the government for specific services. The difference to taxes is that payments and benefits should be proportional.

The fees are directed to a specific cause. Levies or fees are widely used and have been used in an environment and conservation-related context (Meyers et al. 2020). Levies or fees can be paid into environmental funds and provide financing for environmental actions (Meyers et al. 2020).

The use of a levy and a fund has been detailed by Rothauge (2019) who developed a suggestion for an Aftercare Stewardship Scheme. A levy would be imposed on processed biomass products (e.g. wood chips, charcoal, or potentially slaughtered livestock) and paid into a fund. This fund would then finance support services and research necessary for sustainable thinning and post-harvest management.

The establishment of a Sustainable Land Management Trust Fund could coordinate and attract different sources of funds for rehabilitation and restoration purposes, including research on the impact of different post-harvesting measures and support to farmers in maximising the environmental benefits of thinning through pre- and post-harvesting measures.

Donor funding mainly describes multilateral and bilateral aid, which are flows of resources to developing countries and multilateral agencies. The main aim is to promote welfare and economic development and often include technical assistance.

Donor funding could be used to initiate specific programmes (e.g. a post-harvest treatment financing programme) but should be complemented by other sources and a larger scheme – since donors do not finance individuals. Donor funding would have to be channelled through an existing or newly created institution responsible for administering funds (such as a trust fund, as presented above) or through existing institutions.

Securing donor funding will be an essential step to finance research and piloting of innovative bush management measures. However, it is not a sustainable source of finance and cannot be considered enough to finance the implementation of the strategy across bush-thickened landscapes in Namibia.

The contribution of bush thinning and appropriate post-harvesting measures to increasing resilience of Namibian ecosystems to climate change cannot be underestimated. It also contributes to improving the resilience of communities relying on these ecosystems for their livelihoods and directly influences the availability of groundwater – probably the most pressing adaptation issue for Namibia.

Maximising the environmental benefits of bush management can be closely linked to adaptation benefits. **International climate finance** for adaptation is being upscaled by numerous institutions and could be directed towards the financing of certain aspects of sustainable bush management (e.g. research on the specific impact of bush thinning and post-harvest treatments on groundwater).

Major sources of adaptation finance at a global level include EU funding for adaptation, the Adaptation Fund, and the Green Climate Fund.

Adaptation finance could also be used to finance research and pilot projects. Due to their focus on vulnerable communities, projects in communal areas are more likely to attract funding.

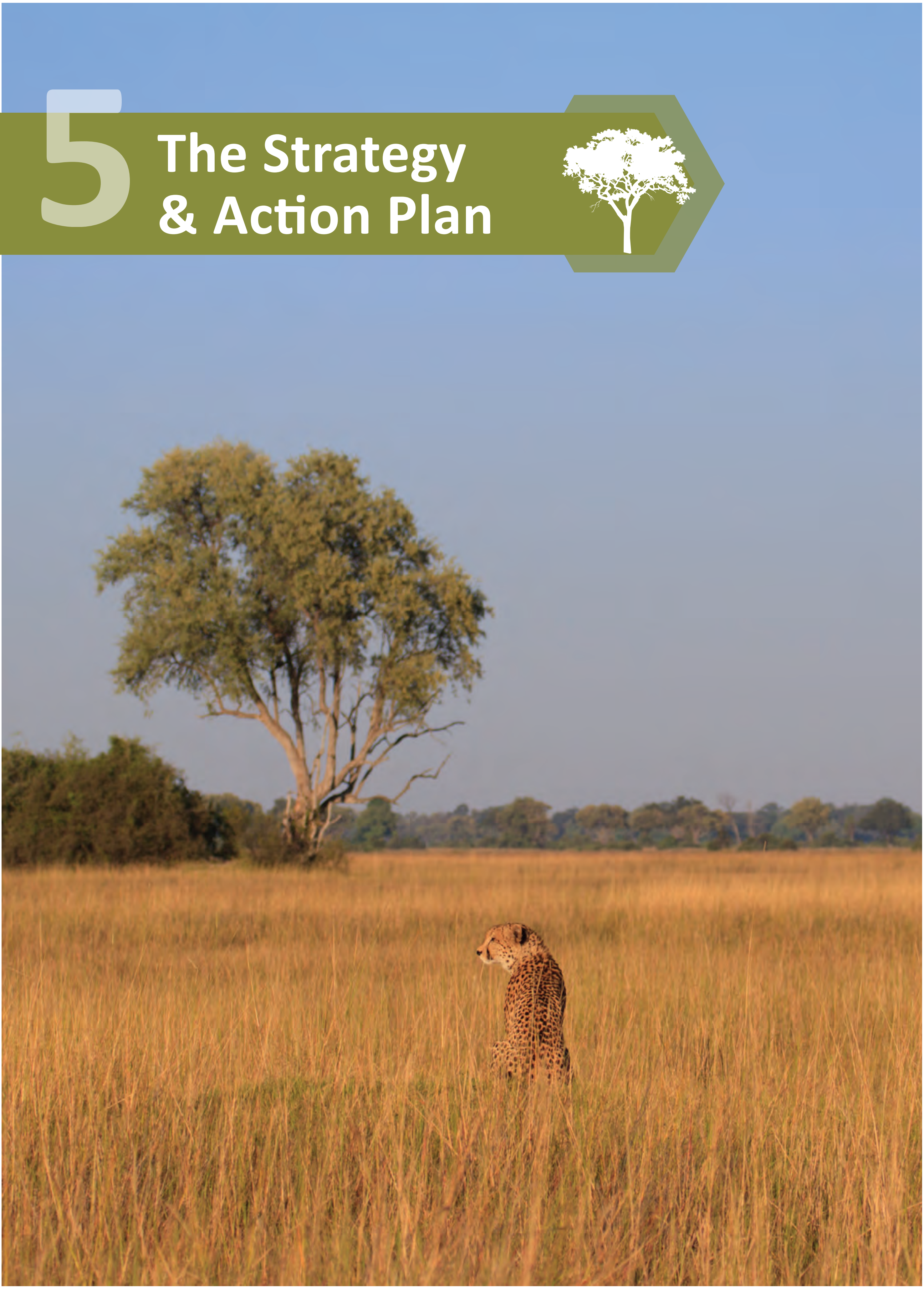
4.4.9 Sector Coordination

The governance of bush resources involves a wide range of sectoral and cross-sectoral stakeholders. Ensuring cooperation between the public and private sector, as well as linking management and use of the resource, can be challenging. Bringing all relevant ministries and stakeholders together to discuss their roles and navigate the complex and multi-disciplinary problem of bush encroachment and bush biomass utilisation is a necessity.

A National Coordinating Committee can enhance information sharing between different actors of the bush resources sector, encourage the exchange of knowledge and best practices, coordinate activities and research and develop appropriate information systems. The committee can also oversee and support the implementation of the strategy and provide a platform for information sharing and data collection.

The committee should involve all relevant ministries and government bodies, civil society and the private sector. The involvement of private sector and civil society stakeholders can drive activities and facilitate the implementation and development of bush control activities and the bush biomass sector, which can boost adaptive capacity.

5 The Strategy & Action Plan



The mission of this strategy is to "promote and facilitate the controlled thinning of bush biomass to encourage the restoration of ecosystems and sustainable economic use of bush resources while ensuring the conservation and enhancement of biodiversity and vital ecological processes such as water and soil nutrient cycling as outlined in international commitments and national development goals".

The following strategic objectives, outcomes and strategies will guide the implementation of the strategy to achieve its mission and overarching objective.

5.1 Strategic Objective 1: Ensure ecologically and socio-economically beneficial bush management.

The extent of bush encroachment in Namibia justifies management interventions to rehabilitate the land for different land uses contributing to improved land productivity and economic development, adaptation to climate change and conservation of biodiversity. However, over-thinning and inadequate post-harvest management techniques can lead to re-thickening and worse degradation. It is vital to use the appropriate management and harvesting techniques to minimise potential adverse impacts on the ecosystem or surrounding areas and address the key causes of bush encroachment.

Outcome 1: By 2030, 15.5 million ha of land will be bush-controlled to maximise environmental benefits.

Due to a lack of guidelines in the past, many farmers have managed bush resources on a trial-and-error basis with often unknown adverse impacts. In recent years, more information has become available to support farmers who wish to conduct bush control. However, a common baseline and framework applicable to all and communicated widely is still missing. A baseline of socio-economic benefits of bush control is also missing. Gender-sensitive indicators should be introduced in this baseline assessment. A common framework must be developed based on the most recent information available. It should emphasise the need for integrated bush management systems, which consider pre- and post-harvest treatments of the land in addition to the bush thinning operation, thereby acknowledging the drivers of bush encroachment and that ecosystem rehabilitation is a continuous process.

A key paradigm shift has been the focus on systems thinking or landscape approaches to conservation, acknowledging the complexity of ecosystems. Bush encroachment and bush control should thus be approached in a holistic way. Instead of focusing on the benefits of bush control for the individual farmer, the focus should be on maintaining the land in a productive state to benefit current and future generations and on securing key ecological processes and services for the greater good. As part of this reframing, land productivity and what constitutes productive land should be defined and evaluated before determining the potential contribution of bush control and sustainable use of bush biomass.

A key target of the Namibian government outlined in the Land Degradation Neutrality National Report (2015) is the reduction of bush encroachment to contribute to enhanced biodiversity and landscape rehabilitation. Namibia's NDCs aim to restore 15.5 million hectares by 2030. To achieve these targets, clear guidelines for the rehabilitation of degraded land and the widespread adoption of specific practices are a necessity. They should address biodiversity considerations; climate change adaptation, improving soils and soil organic carbon, low carbon development and clean production technologies; enhancing the availability of groundwater, diversifying income sources and contributing to a stable and resilient ecosystem that can sustain key services such as game farming and wildlife tourism.

Strategies:

- Establish an ecological baseline of bush encroachment in Namibia.
- Establish a baseline of practices, bush control activities and socio-economic impacts of bush control.
- Improve knowledge on sustainable harvesting.
- Clarify the contribution of bush control to climate change mitigation and adaptation.
- Promote measures that protect intact savannas or halt encroachment at an early stage to avoid land degradation.
- Establish clear guidelines on how to conduct sustainable harvesting, including safeguards on risky measures.
- Strengthen the use of decision support systems.

Outcome 2: By 2026, unsustainable practices and further degradation will have been reduced by incentivising sustainable practices in bush control and land management, and post-harvest measures will have been adopted by at least 50% of farmers involved in bush control.

Aerial spraying and clear-cutting of land are not permitted by Namibian regulations but are still practised and are in fact allowed under certain conditions. Unselective methods are driven by the high costs of many bush control methods and post-harvest treatments. In many cases, mechanical and chemical means of control as well as chemical post-harvest treatments are the more cost-effective options for farmers in the short and medium term. However, the broader impact on the environment and associated benefits of environment-friendly practices are not included in these cost and benefit calculations. Practices that could degrade the wider range of ecosystem services should be reduced and phased out in the medium to long term. As a result, there is a clear need to promote and incentivise more responsible practices considering long-term impacts, minimising land degradation and ensuring the maintenance of ecosystem services.

This also includes post-harvest measures: Positive impacts after bush thinning are often short-lived and most bush species quickly re-establish themselves, increasing competition with grasses. Post-harvest treatments are vital to maintain the balance between woody biomass and grasses in the long term and provide the basis for integrated bush management systems. Integrated systems consider the timing of initial thinning, and follow-up treatments often involve various preventive and restorative measures.

Strategies:

- Identify current drivers that favour the use of different practices and their impacts.
- Identify options to incentivise best practices that minimise damage to the environment and enhance ecosystem services in the longterm.
- Develop incentives for the adoption of best practices that minimise damage to the environment and enhance ecosystem services in the longterm, including post-harvest measures.
- Raise awareness and understanding of the importance of post-harvest treatments.

Outcome 3: By 2023, governance frameworks and management systems for sustainable bush control and management in communal areas will have been identified.

Due to the common-pool nature of bush resources in communal areas, a different governance framework and management system is required to ensure adequate benefits for those rehabilitating land and using bush biomass, while ensuring a stable supply of the resource for other users who depend on natural resources for their subsistence.

Strategies:

- Assess the state of bush resources in communal areas.
- Define a governance system and best practices for bush management and use in communal areas.
- Apply or adapt existing management frameworks to bush resource use and value chain development activities in communal areas.
- Demonstrate and ensure the viability of bush businesses in communal areas.

5.2 Strategic Objective 2: Enhance monitoring and evaluation capacity.

Monitoring is key to ensuring responsible control of bush resources and maintenance of a diverse landscape and functioning ecosystem in the long term. Current limitations in monitoring capacity allow the use of unsustainable practices with possibly detrimental impacts on the landscape.

Outcome 4: By 2023, the extent of bush encroachment, bush control, post-harvest treatment and sustainable use of bush resources will be monitored, collated and analysed to inform decision-making and enable adaptive management.

A cornerstone of monitoring is the collection of adequate data to support management decisions and evaluate their performance. Current decision-making is heavily reliant on old or incomplete information such as the Bester Map of the distribution of thickening species or several estimates of the extent of bush thickening in Namibia.

A systematic approach with consideration of the use of digital applications for collecting data, which can be used at different levels by various stakeholders, can considerably contribute to closing knowledge gaps for more informed decision-making and better monitoring. Cross-dissemination of knowledge and collaboration are vital to determine the most effective ways to monitor bush resources in Namibia.

Key indicators to guide monitoring and evaluation efforts will be developed to ensure that bush resources in Namibia are managed to reduce land degradation, improve land productivity, enhance biodiversity and contribute to the resilience of the ecosystem to climate change. To better assess socio-economic impacts, gender disaggregated data should be collected.

Strategies:

- Improve monitoring frameworks for the management of bush resources.
- Improve the capacity of extension services for monitoring forest and bush resources.
- Test and adopt innovative monitoring methods.
- Upgrade monitoring systems.
- Conduct regular monitoring based on monitoring plans.
- Promote adaptive management.

5.3 Strategic Objective 3: Promote coordinated and collaborative research.

Research can considerably contribute to enhancing the knowledge base for informed decision-making, adaptive management, sustainable bush control and the development of different value chains using bush resources. To maximise the contribution of research to good management of bush resources, it should be aligned with research gaps, needs and priorities. Research should inform bush management on the ground and subsequent monitoring efforts should inform research to ensure targeted solutions.

Outcome 5: By 2023, improved collaboration on research surrounding bush management will guide decision-making and adaptive management.

To ensure that research meets the needs of resource managers and bush-based industries, a framework for research should be developed through a collaborative process. It should clearly outline roles and responsibilities of different organisations and ways to collaborate. Research priorities should be assigned to address capacity limitations of various institutions.

Strategies:

- Strengthen collaboration in research surrounding bush resources between different stakeholders.
- Establish systems for exchanging and accumulating knowledge.

Outcome 6: By 2023, the scientific knowledge and information around sustainable bush management will have increased significantly and will be developing continuously.

Based on research priorities, key knowledge gaps on the sustainable management of bush resources will be filled and shared with landowners, resource users and other relevant stakeholders to adapt and improve bush management practices.

Strategies:

- Develop priority areas for research and assign responsibilities and funding.
- Enhance research and showcase applied research examples.

5.4 Strategic Objective 4: Create awareness and understanding of guidelines and best practices among all stakeholders.

To ensure that the outcomes under the other strategic objectives are achieved, the dissemination of knowledge and creation of awareness among institutions and resource users in different areas of the country is vital.

Outcome 7: By 2024, at least 50% of landowners and contractors and 50% of forestry personnel will have been reached through capacity building and awareness.

Guidelines on responsible use and monitoring of bush resources must be communicated to farmers affected by bush encroachment and institutions involved in bush control and bush biomass use across the country. To ensure that the correct information is disseminated and well understood, the knowledge and capacity of trainers must be improved.

However, creating knowledge and awareness should not be a top-down process alone. It is important to acknowledge the experiences of harvesters and encourage dialogue to develop best practices for different contexts, regions and species. Capacity-building should particularly target disadvantaged groups and women to promote inclusivity.

Strategies:

- Address capacity building needs.
- Raise awareness on guidelines.

Outcome 8: By 2026, key stakeholders nationally and internationally will have been sensitised about bush encroachment challenges and opportunities.

Inconsistencies in information sharing and reporting on bush encroachment has created information asymmetries between different levels of society at regional, national and international level. Consistent and concise information on bush encroachment and Namibia's plans to address this challenge while enhancing ecological and socio-economic benefits should be available and easy to access for national and international funding institutions and key policymakers.

Strategies:

- Identify information, knowledge and communication gaps and develop narratives and information material that can be used for national and international communication and funding proposals.

5.5 Strategic Objective 5: Appropriate financial resources are raised to fund implementation and incentive mechanisms.

Lack of resources and limited access to finance are a key problem to financing bush control and monitoring in Namibia. Incentives and regulations are required to ensure the sustainable management of bush resources and the positive contribution of bush control to restoration and rehabilitation objectives, as well as economic development and human wellbeing. Inadequate funding can be a considerable constraint to the sustainable management of bush resources.

Outcome 9: By 2026, at least N$1 billion will have been raised from private and public sources to support the implementation of the strategy.

To ensure the implementation of the strategy, funding from various sources is required. It cannot be achieved with public finance alone and should rely on diverse funding sources ranging from domestic public finance, donor finance and conservation funds to private finance. Some options are outlined in the Financing Plan (Chapter 7).

Strategies:

- Develop a resource mobilisation strategy.
- Enhance the diversification of financing tools and funding sources.
- Enhance public-private cooperation and partnerships to establish incentive mechanisms.

5.6 Strategic Objective 6: Coordination and cooperation around bush management improves.

Outcome 10: By 2023, a platform responsible for the coordination of relevant activities across sectors and information sharing will have been created.

A National Coordinating Committee can enhance information-sharing between different actors of the bush resources sector, encourage the exchange of knowledge and best practices, coordinate activities and research and develop appropriate information systems. Such a committee can also oversee and support the implementation of the strategy and provide a platform for information-sharing and data collection.

Strategies:

- Establish a Coordinating Committee for government, private sector and civil society to engage around issues of bush management.
- Promote cooperation and integrated decision-making between stakeholders through the Coordinating Committee.
- Enhance cooperation and knowledge exchange.

Table 6 Strategic Objectives

Outcomes

Strategies	Actions	Baseline	Indicators	Relevant Institutions
SO1: Ensure ecologically and socio-economically beneficial bush management.				
O1: By 2030, 15.5 million ha of land will be bush-controlled to maximise environmental benefits.				
1.1. Establish an ecological baseline of bush encroachment in Namibia.	• Establish and verify the extent of bush encroachment in Namibia with more ground truthing. • Assess impacts of bush encroachment on land degradation and the ecosystem in various landscapes across Namibia. • Gather historical records and accounts to assess the former state of landscapes. • Compare local biodiversity to the biodiversity in comparable biotopes and landscapes. • Establish a clear list of encroaching species that may be controlled, specifying to what extent for different areas.	Detailed mapping in Otjozondjupa & Omusati (LDN Assessment) Less precise maps for the rest of the country Land degradation baseline assessment (ongoing)	Report compiled for main bush encroached areas.	MEFT-DEAF, NSA, NUST, UNAM, N-BiG, NCA
1.2. Establish baseline of practices, bush control activities and socio-economic impacts of bush control.	• Conduct regular surveys to determine methods used, type of bush products throughout the country and record the experiences of different land-users with these methods. • Conduct surveys to collect data on employment, income, gender and social characteristics of actors involved in bush value chains. • Institutionalise surveys and secure funding for regular surveys.	One survey in 2020 (M&E N-BiG)	Number of surveys Available funding	MEFT-DEAF, N-BiG, NSA, NUST, UNAM, NCA
1.3. Improve knowledge on sustainable harvesting.	• Conduct research on the ecological impact of different thinning and post-harvest measures. • Assess contribution of bush control to reversing land degradation and enhancing biodiversity depending on methods used. • Examine national and international best practices for the rehabilitation of degraded land and determine feasibility of different measures in Namibia. • Identify key management interventions to improve land productivity and ecosystem functioning. • Establish best practice pilot farms and demo plots and encourage knowledge transfer through site / exchange visits within and between different land tenure types.	Existing local studies on harvesting. MAWLR - DARD research on aftercare.	# of research projects on ecological impacts # demo plots / pilot farms established Best practices identified and established.	MEFT-DEAF, MAWLR-DARD, UNAM, NUST, N-BiG, NCA

1.4. Clarify the contribution of bush control to climate change mitigation and adaptation.	• Assess the carbon stored and the distribution of carbon in bush encroached areas vs. wooded savannas in different biotopes. • Assess the potential positive and negative impacts of different measures on carbon stocks. • Establish the cost of no-action for local communities, farmers' resilience and adaptive capacity to the impact of climate change. • Identify key adaptation benefits related to bush control and post-harvesting interventions. • Assess the potential value of these adaptation benefits for Namibia.	Existing indirect studies and assessments[2] SOC Data for Otjozondjupa	# of ha covered by carbon assessment Primary data and study on groundwater recharge Study on Cost of No-Action	MEFT-DEAF, MAWLR, UNAM, NUST, CCF
1.5. Promote measures that protect intact savannas or halt encroachment at an early stage to avoid land degradation.	• Assess areas at risk of encroachment or showing early stages of encroachment. • Establish common best practices to prevent encroachment in areas at risk and mitigate early-stage encroachment (in line with sustainable rangeland management promoted by farmer's unions). • Disseminate knowledge on these practices in targeted areas.	Risk areas identified in Land Degradation Strategy	Area at risk (ha) Best practices established, and disseminated	MEFT-DEAF, MAWLR, UNAM, NUST, N-BiG, NAU, NECFU, NNFU
1.6. Establish clear guidelines on how to conduct sustainable harvesting, including safeguards on risky measures	• Develop and agree on clear guidelines for practices to rehabilitate degraded land and maximise environmental benefits based on the existing legislative environment. • Develop Standard Operating Procedures for sustainable bush harvesting. • Encourage the development of integrated bush management plans, which include pre- and post-harvest treatment programmes. • Identify options to encourage larger management units for the sustainable use of bush resources. • Develop guidelines for management plans at a systems level (e.g. farm, grazing area, ecosystem). • Develop assessment and mitigation frameworks for risky control methods. • Include mitigation frameworks / safeguards in guidelines. • Communicate known impacts and best practices among land users and ensure that information is accessible and distributed through various means including websites, brochures, posters, extension services etc.	MEFT & MAWLR Harvesting Guidelines DAS: Labour-based harvesting guidelines, DSS NRMP&S / Regenerative Agr. Strategy (NAU) Namibia FSC Standards Forest Act and other Environmental Legislation	# of farmers / people that adopted the guidelines Updated best practice guides. SOPs established. Safeguards included in guidelines.	MEFT-DEAF, MAWLR-DARD, FSC, NCA, N-BiG Farmers' Unions

[2] UNIQUE (2019). Greenhouse Gas Assessment of Bush Control and Biomass Utilisation in Namibia, GIZ Namibia; Cirrus Capital (2021). Update of an existing Macroeconomic Impact Assessment for a Biomass Power Station in the Oshikoto region, Draft report, NamPower; Birch, C. and Middleton, A. - NNF (2016). An assessment of the economics of land degradation related to bush encroachment in Namibia, Namibia Nature Foundation, Ministry of Agriculture, Water and Forestry, Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ). NNF (2021) Environmental impact assessment and cost-benefit analysis of post-harvest measures. Namibia Nature Foundation, Deutsche Gesellschaft für international Zusammenarbeit (GIZ). NNF (2021) Assessment of Vulnerability and Adaptation Potential of the Otjikoto Biomass Power Project, NamPower.

1.7. Strengthen the use of decision support system (DSS).	• Assess the alignment of existing support systems with the strategy. • Identify potential gaps in existing decision support systems. • Modify the DSSs if necessary and integrate them if possible. • Make all DSSs accessible on one platform and link with existing monitoring or assessment systems (e.g. to BIS). • Organise promotion events to spread the use of DSS.	Many DSSs not harmonised (DAS, NUST, NAU).	Updated and harmonised DSS # of people using DSS system	MEFT, MAWLR, N-BiG, NUST, UNAM
O2: By 2026, unsustainable practices and further degradation will have been reduced by incentivising sustainable practices in bush control and land management, and post-harvest measures will have been adopted by at least 50% of farmers involved in bush control.				
2.1. Identify current drivers that favour the use of different practices and their impacts.	• Conduct a study on choice criteria and best practices for different measures. • Test favoured methods through field experiments where knowledge gaps exist. • Assess the ecological impacts, effectiveness and cost of using arboricides for bush control. • Assess the cost and benefits of using different measures in different landscapes with differences in soil, rainfall and encroaching species.	Aftercare CBA Aftercare Stewardship Scheme report	# of studies conducted # methods assessed and tested	MEFT, MAWLR, NUST, UNAM, NGOs
2.2. Develop incentives for the adoption of best practices that minimise damage to the environment and enhance ecosystem services in the long term, including post-harvest measures.	• Identify incentive mechanisms including financial, regulatory, and commercial, and assess the feasibility and viability of using these mechanisms for bush management. • Determine the costs of different post-harvest treatment measures. • Feasibility study for three targeted incentive mechanisms. • Engagement with potential implementing institutions (banks for concessional loans, Forest Stewardship Council for certification.) • Pilot and upscale chosen mechanisms.	Concept note on Aftercare Stewardship Scheme Aftercare EIA and CBA MAWLR-DARD research on post-harvest measures FSC PES (Payment for Ecosystem Services)	# of incentive systems identified # of incentives implemented Financing mechanism for post-harvest measures established Adoption of appropriate legal framework	MoF, MEFT, MAWLR, FSC, N-BiG, NCA, Farmers' Unions NamPower, NUST, UNAM, AgriBank, DBN, Commerical Banks
2.3. Raise awareness and understanding of the importance of post-harvest treatments.	• Pilot the combination of different post-harvest treatment measures and assess their performance. • Assess the effectiveness and impacts of using arboricides for aftercare. • Raise awareness among farmers on costs and benefits of post-harvest treatments through workshops and knowledge material. • Launch an education programme for on-field demonstrations of best practices and knowledge exchange (e.g. farmers' information days).	Capacity-building programme of N-BiG NTA (Industry Qualifications on Bush Biomass) MAWLR DARD Research Aftercare EIA and CBA	# pilots on combined post-harvest measures # workshops and farmer's training Education programme established # of field demonstrations/ knowledge exchange events # of farmers who adopted post-harvest measures	MEFT, MAWLR, N-BiG, NCA, NamPower, FSC, Farmers' Unions

O3: By 2023, governance frameworks and management systems for sustainable bush control and management in communal areas will have been identified.				
3.1. Assess the state of bush resources in relevant communal areas.	• Consolidate information and assess the extent of bush resources and main encroaching species in communal areas. • Include a specific section on communal areas in the baseline assessment on the current uses of bush resources (Strategy 1.1). • Assess resource availability and estimate the potential local bush offtake for own and commercial uses for current and new activities. • Assess and record any traditional knowledge on bush resources and their use.	Resource Assessments when registering community forests. IRLUPs BIS	# of ha of bush encroached land in communal areas Annual biomass offtake established Traditional knowledge on use established	MEFT, MAWLR, N-BiG
3.2. Define a governance system and best practices for bush management and use in communal areas.	• Assess key risks and challenges as well as opportunities for bush control and the use of biomass in communal areas, including disadvantaged groups and women. • Identify gaps in the governance framework of common pool resources and potential solutions based on existing community-based governance and management structures such as community forests and collectives. • Identify suitable bush thinning methods, post-harvest treatments and value chains for communal areas. • Conduct pilots on the management of bush resources, monitor the impacts on the resource base and assess the economic and gender impact through the benefit-sharing system in place. • Trial suitable methods for bush thinning and post-harvest treatments in communal areas. Provide training targeting women.	One pilot with three sites in communal areas	Governance framework and SOPs established # of pilots # of communal farmers trained	MEFT, MAWLR, N-BiG, UNAM, NCA, NNFU/ NECFU, CBOs
3.3. Apply or adapt existing management frameworks to bush resource use and value chain development activities in communal areas	• Equip existing management structures such as community forests and PPOs with the knowledge to manage bush resource. • Introduce bush-related indicators and management considerations into management plans of community-based organisations. • Communicate clear guidelines on what is considered own use rights and commercial use rights in areas that are not community forests.	One pilot with three sites in communal areas	Clear guidelines for communal areas. # PPOs or community forests involved in bush management Bush indicators in management plans.	MEFT, MAWLR, N-BiG, UNAM, NCA, NNFU/ NECFU, CBOs
3.4. Demonstrate and ensure the viability of bush businesses in communal areas	• Develop viable business cases for communal areas (e.g. joint ventures) and encourage research on cost-effective measures for communal areas. • Develop partnerships and explore joint ventures. • Establish or integrate a dedicated benefit-sharing system for bush harvesting and biomass use. • Pilot the benefit-sharing system and identify best practices.	Pilot in African Wild Dog Conservancy by UNAM FSC pilot in communal areas GIZ pilot on labour-based encroacher bush harvesting	Business case developed / established. # of partnerships established. Benefit-sharing systems piloted	MEFT, MAWLR, N-BiG, UNAM, NCA, NNFU/ NECFU, CBOs, NGOs

SO2: Enhance monitoring and evaluation capacity.				
O4: By 2023, the extent of bush encroachment, control, post-harvest treatment and sustainable use of bush resources will be monitored, collated and analysed to inform decision-making and enable adaptive management.				
4.1. Improve monitoring frameworks for the management of bush resources.	• Assess monitoring needs by various institutions and individuals. • Identify appropriate indicators relevant for the management of bush resources considering land-uses, land productivity and restoration targets. • Define soil quality, land degradation, biodiversity, and land productivity indicators applicable to bush encroached landscapes with a clear definition of ideal targets by landscape. • Develop a framework to assess carbon stocks in bush resources. • Integrate different monitoring systems and develop frameworks for pre- and post-harvesting assessments. • Establish baselines and a monitoring plan for the different indicators.	Forest Inventory Permitting / ECC inspections FSC certification inspections Rangeland monitoring application	Monitoring needs identified. Indicators established, defined and integrated into existing processes (BIS). Carbon stock assessment framework established.	MEFT: DEAF & Scientific Services, NUST, UNAM, FSC, N-BiG, farmers' unions
4.2. Improve the capacity of extension services for monitoring forest and bush resources.	• Identify knowledge gaps and training needs of staff responsible for monitoring bush resources. • Train DoF and DAPEES staff in Windhoek and regional offices on different monitoring methods. • Assign resources (personnel, equipment etc.) to the efforts of monitoring bush control. • Review processes and systems to better monitor compliance with regulations.	Capacity-building programme N-BiG Law enforcement training for DoF	Develop training programmes for extension services # training courses for DoF staff and DAPEES Allocated budget for DoF monitoring activities	MAWLR -DAPEES, MEFT-DEAF, MAWLR-DARD, N-BiG, UNAM, NUST
4.3. Test and adopt innovative monitoring methods.	• Identify current monitoring methods used and new and innovative methods that could be used. • Identify best practices for monitoring woodland resources in other countries and assess their applicability for Namibia. • Assess cost and feasibility of different technologies for monitoring. • Promote research on innovative methods to monitor bush resources. • Trial methods in Namibian context and evaluate their performance.	Pilots on use of drones Remote Sensing Center at DoF Biomass quantification tool	# of innovative methods piloted and adopted Feasibility, performance and costs are assessed.	MEFT- DEAF, N-BiG, NUST/NSA
4.4. Upgrade monitoring systems.	• Define suitable monitoring methods as well as roles and responsibilities of different stakeholders and implementing arrangements. • Establish a self-monitoring framework (in coordination with relevant stakeholders) that can be used on farm-level and for evaluations at a higher level. • Integrate the monitoring of bush resources into community forest inventories, EIAs and permitting inspections. • Integrate the Bush Information System (BIS) into existing MEFT monitoring efforts. • Include assessment of carbon stocks into management plans and self-monitoring frameworks.	Forest Inventory Permitting / ECC inspections FSC certification inspections	BQT and BIS integrated into existing monitoring system. Carbon and other biodiversity indicators are integrated into existing processes.	MEFT-DEAF, NUST, UNAM, FSC, N-BiG, farmers' unions

4.5. Conduct regular monitoring based on monitoring plans.	• Collect and analyse field samples to assess indicators before and periodically after bush control for different methods and management regimes. • Ensure the collection of data that can assist the evaluation of economic performance of different interventions. • Periodic update and mainstreaming of the bush information system by relevant institutions.	Forest Inventory (every five years) Permitting / ECC inspections FSC certification inspections BIS baseline N-BiG M&E survey	# of field samples analysed. Frequency of monitoring Frequency of BIS updates	MEFT-DEAF, NUST, UNAM, FSC, N-BiG, farmers' unions
4.6. Promote adaptive management.	• Promote learning and best practices by encouraging knowledge dissemination between and among commercial and communal farmers and different institutions involved in the sector. • Review strategy and guidelines every five years based on new knowledge. • Promote the review and update of farm-level management plans on a regular basis (5 - 10 years).	0: Strategy did not exist Exchange visits	Frequency of reviews	MEFT, MAWLR, N-BiG
SO3: Promote coordinated and collaborative research.				
O5: By 2023, improved collaboration on research surrounding bush management will guide decision-making and adaptive management.				
5.1. Strengthen collaboration on research surrounding bush resources between different stakeholders.	• Define roles and responsibilities of different institutions conducting research on bush resources and rangeland management. • Establish partnerships between DoF, the industry and academia (national and international). • Identify funding institutions for research and increase opportunities for joint funding applications.	Some collaboration between industry and universities (N-BiG, NUST, UNAM), not formalised.	# Joint research proposals/ research MoUs # Collaboration with international research	MEFT-DEAF, MAWLR-DARD, Ministry of Higher Education, UNAM, NUST, IUM-CES, NCRST, NBRI, NSA
5.2. Establish systems for exchanging and accumulating knowledge.	• Identify suitable processes and information systems to pool and share information and data on bush resources and their management. • Compile and synthesise existing data and make it accessible to all. • Define responsible institutions for data hosting and analysis.	N-BiG Advisory Service resources website EIS BIS	One resource platform established and updated regularly (repository)	N-BiG, NUST, UNAM, farmers' unions, NCA, NCRST, NBRI, Ministry of Higher Education, NSA
O6: By 2023, the knowledge and science around sustainable bush management will have improved.				
6.1. Develop priority areas for research and assign responsibilities and funding.	• Consult policymakers and harvesters / farmers to identify knowledge gaps. • Assess capacity gaps in conducting research. • Establish a joint 5-year research plan on bush control and associated practices, including responsible entities and potential funding sources.	No common research plan	Common research plan established with MEFT and academia.	MEFT, MAWLR-DARD, NUST, UNAM, IUM, N-BiG

[3] http://www.namibiarangelands.com/products/ and associated Rangeland Fodder Flow Planner mobile application.

6.2. Enhance research and showcase applied research examples.	• Expand joint research efforts • Present research results to policymakers and farmers / harvesters, e.g. through field demos and demo plots and via a dialogue platform	NUST research projects / Symposium research outputs MALWR-DARD research UNAM research projects	# peer-reviewed publications # results presentations/ dissemination	MEFT, MAWLR-DARD, NUST, UNAM, IUM, N-BiG
SO4: To create awareness and understanding of guidelines and best practices among all stakeholders.				
O7: By 2024, at least 50% of landowners and contractors and 50% of Forestry personnel have been reached through capacity building and awareness.				
7.1. Address capacity-building needs.	• Assess capacity gaps within different institutions in the government, civil society and private sector. • Identify and strengthen institutions with the necessary knowledge and expertise to fill these gaps. • Design training and education programmes around priority areas, pooling different key topics into workshops and training designs for harvesters and monitors, with an emphasis on the inclusion of women.	N-BiG capacity-building programme NCA training FSC training Farmers' Union training on regenerative agriculture NTA training (needs assessment facilitated by N-BiG).	# people/ institutions trained # education programme developed % of women trained	MEFT-DEAF, farmers' unions, N-BiG, FSC
7.2. Raise awareness on guidelines.	• Ensure that simple and short guidelines are created and distributed to farmers and other institutions on key topics around the sustainable management of bush resources.	DSSs MAWLR/MEFT Harvesting guidelines DAS harvesting booklet	Guidelines synthesised, updated and disseminated Training Manual	MEFT-DEAF, MAWLR, farmers' unions, N-BiG, FSC
O8: By 2026, key stakeholders nationally and internationally will have been sensitised about bush encroachment challenges and opportunities.				
8.1. Identify information, knowledge, and communication gaps and develop information material that can be used for national and international communication and funding proposals.	• Consult policymakers and public relations experts to assess gaps. • Target key institutions and individuals (parliament, specific ministries and staff, NGOs, banks). • Establish a clear narrative and communication plan based on the national strategy via a dialogue platform. • Print leaflets, posters and policy briefs on the national strategy, including key outcomes. • Disseminate the strategy across institutions (prints and presentations).	Some gaps identified through Hamburg process/ NamPower experience. No clear accessible storyline and communication tools on bush harvesting in Namibia.	Gaps and discrepancies clearly identified Narrative established # stories published on various national and international media # copies of strategy distributed and presented # position papers published	MEFT, MAWLR, N-BiG, media, farmers' union, civil society, commercial banks

SO5: Appropriate financial resources are raised to fund implementation and incentive mechanisms.				
O9: By 2026, at least N$1 billion will have been raised from private and public sources to support the implementation of the strategy.				
9.1. Develop a resource mobilisation strategy.	• Detailed cost assessment of the strategy. • Assess available resources for the implementation of the strategy. • Identify potential funding sources, including research already covered under the draft Optimisation Strategy.	No resource mobilisation strategy (financial mechanism review for aftercare)	Resource mobilisation strategy established	MEFT, EIF
9.2. Enhance the diversification of financing tools and funding sources.	• Explore funding potential from impact investors and develop partnerships with impact investing platforms. • Explore potential for adaptation funding and develop appropriate capacity to access these funds.	Commercial banks and Agribank loans FSC PES (in progress) EIF small grants	# funding proposals for adaptation funding # Impact investors consulted # financing tools / funding resources identified	MEFT, EIF, Namibia Investment Centre, N-BiG
9.3. Enhance public-private cooperation and partnerships to establish incentive mechanisms.	• Explore potential for blended finance tools to incentivise sustainable practices through cooperation between government and private financial institutions (private banks and investors). • Assess the feasibility of labelling different products through cooperation between industry, standards institution and environment stakeholders. • Promote the establishment of associations for capacity-building and fundraising to increase accessibility to certifications for available labels.	Commercial banks and Agribank loans FSC PES (in progress) EIF small grants	# financial incentives established Feasibility labelling established # fundraising associations established	MEFT, commercial banks, EIF, DbN, Agribank
SO6: Coordination and cooperation around bush management improves.				
O10: By 2024, a platform responsible for the coordination of relevant activities across sectors and information-sharing will have been created.				
10.1. Establish a Coordinating Committee for government, private sector and civil society to engage around issues of bush management.	• Assess existing capacity and structures in place to identify the most appropriate institution that could host a coordinating platform. • Map out key stakeholders relevant to bush resources and their sustainable use, assessing their roles and responsibilities. • Assess possible options for the creation of a common platform / coordinating body. • Discuss the potential scope and objectives of a bush platform. • Establish and operationalise the platform.	Steering committee of BCBU Governance scoping report	National Coordinating Committee established	MEFT, MAWLR, NPC, MIT, MME, NamPower, NCA, N-BiG, farmers' unions, civil society, MURD, MoL, NUST, UNAM, IUM, Agronomic Board, Meat Board, AgriBank, commercial banks, DBN

10.2. Promote cooperation and integrated decision-making, between stakeholders through the Coordinating Committee.	• Identify ongoing projects and find potential synergies. • Identify key areas that require more collaboration, coordination, and knowledge exchange. • Mainstream the strategy objectives into national development objectives such as the NDP6. • Establish a dialogue platform and support the development of a knowledge sharing platform/repository. • Coordinate with the NRMP&S and associated stakeholders on holistic and sustainable management initiatives. • Collaborate with MAWLR to include bush encroachment and land degradation indicators in IRLUPs.	No integrated decision-making system. Governance Scoping Report and Policy Review	# of inter-ministerial meetings organised # of coordination committee meetings Overview of projects	MEFT, MAWLR, MIT, N-BiG, NCA, NamPower
10.3. Enhance cooperation and knowledge exchange.	• Evaluate the options for a common database for data collected on bush resources. • Develop, maintain, and regularly update a shared database on bush resources.	N-BiG Advisory Service resources website EIS BIS	One resource platform established and updated regularly	MEFT, MAWLR-DARD, N-BiG, NUST, UNAM, farmers' unions, NCA, NSA

6 Monitoring and Evaluation Framework

This monitoring and evaluation framework serves to track ongoing processes under this strategy and to evaluate the performance of different activities conducted. The monitoring framework is based on the strategic objectives outlined in the previous chapter.

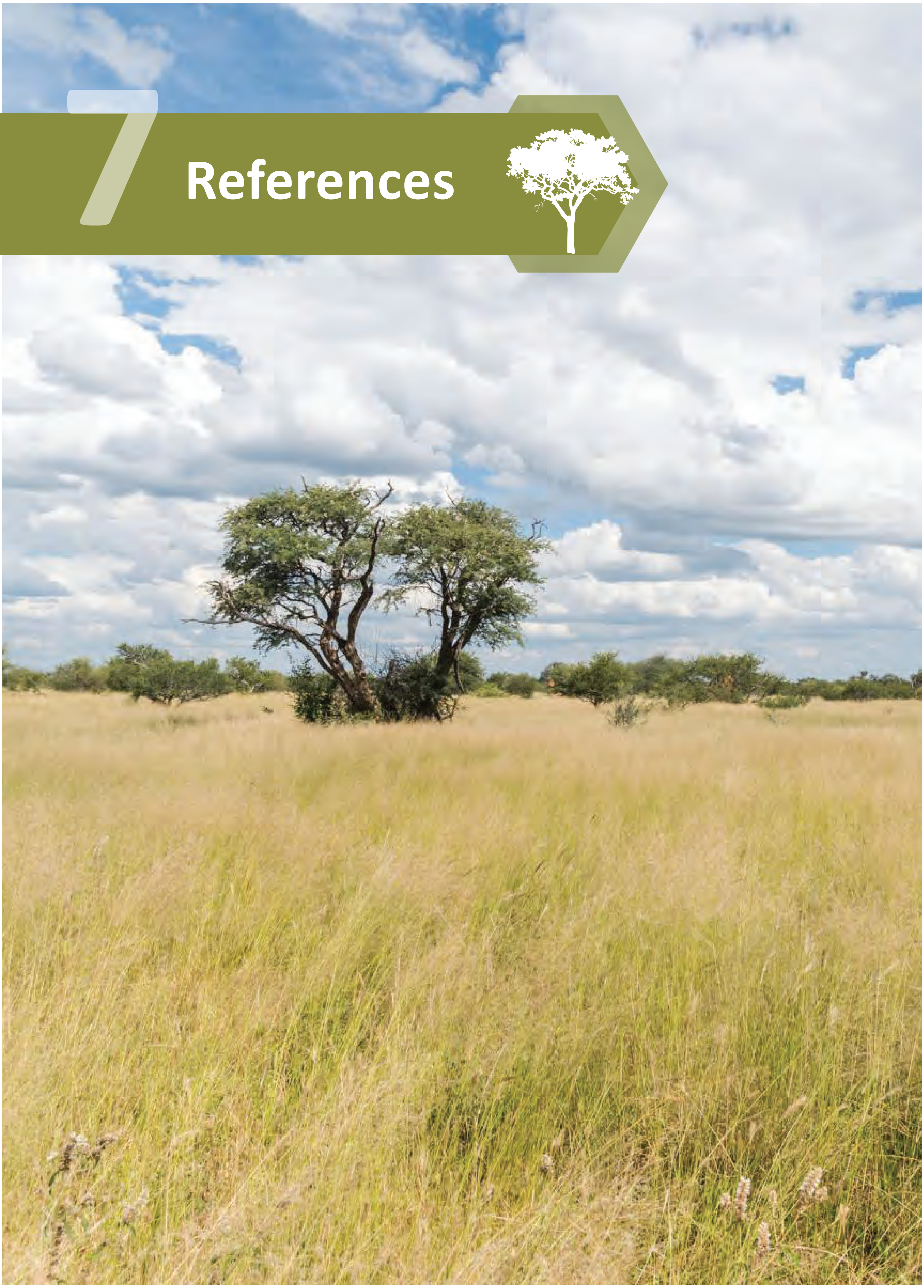
Monitoring and evaluation should be a continuous process and should be adapted as soon as new knowledge becomes available to ensure alignment with other relevant polices, strategies and regulations.

The responsible entity shall report on progress on the 10 outcomes, indicators for specific initiatives and total expenditure per initiative to evaluate performance and efficiency of activities under this strategy.

Bush encroachment and its effects, bush control, the use of bush resources as well as requirements to ensure the rehabilitation to a desired landscape have received considerable attention in recent years. However, baselines are still missing in many instances. Establishing baseline data will be one of the key aims of this strategy and action plan.

The monitoring and evaluation of this strategy will be coordinated by the Directorate of Forestry and Environmental Affairs in the Ministry of Environment, Forestry and Tourism. Progress should be evaluated and reported on an annual basis.

7 References



Agra (2015). Survey development and implementation in preparation of a De-bushing Advisory Service (DAS). Conducted by Dagmar Honsbein for the MAWF / GIZ Support to De-bushing Project.

Archer, S.R. and Predick, K.I. (2014). An ecosystem services perspective on brush management: research priorities for competing land-use objectives. J Ecol, 102: 1394-1407. https://doi.org/10.1111/1365-2745.12314

Archer, S.R., Andersen, E.M., Predick, K.I., Schwinning, S., Steidl, R.J. & Woods, S.R. (2017). Woody Plant Encroachment: Causes and Consequences. In: Briske D. (eds) Rangeland Systems. Springer Series on Environmental Management, pp 25-84. https://doi.org/10.1007/978-3-319-46709-2_2

Baldiga, J., Graham, K., Rosenfelder, L. & Van Ness, Z. (2008). Bush Harvesting Sustainability Through Accommodation and Aftercare Recommendations. Worchester Polytechnic Institute & DRFN. https://digital.wpi.edu/concern/student_works/db78tc434?locale=de

Birch, C., Harper-Simmonds, L., Lindeque, P. & Middleton, A. (2017). Namibia Case Study: Bush control generates economic and environmental benefits. Commissioned by the MAWF / GIZ Support to De-bushing Project and the ELD Initiative. https://www.eld-initiative.org/fileadmin/pdf/ELD-CS_namibia_04_web_300dpi.pdf

Blaum, N., Seymour, C., Rossmanith, E. & Schwager, M. (2009). Changes in arthropod diversity along a land use driven gradient of shrub cover in savanna rangelands: identification of suitable indicators. Biodivers Conserv 18, 1187-1199. DOI:10.1007/s10531-008-9498-x

Boutton, T.W., Liao, J.D., Filley, T. & Archer, S.R. (2009). Belowground carbon storage and dynamics accompanying woody plant encroachment in a subtropical savanna. In Soil Carbon Sequestration and the Greenhouse Effect, pp 181-205, 2nd ed.; Lal, R. & Follett, R., Eds.; Soil Science Society of America.

Boys, J.M. & Smit, G.N. (2020). Development of an Excel Based Bush Biomass Quantification Tool. Final Report to the MEFT / GIZ Bush Control and Biomass Utilisation Project

Buyer, J.S., Schmidt-Künzel, A., Nghikembua, M., Mail, J.E. & Marker, L. (2016). Soil microbial communities following bush removal in a Namibian savanna. Soil Journal 2, 101 - 110, https://doi.org/10.5194/soil-2-101-2016

Christelis, G. & Struckmeier, W. (2011). Groundwater in Namibia - an Explanation to the Hydrogeological Map. Windhoek. Retrieved from https://www.bgr.bund.de/EN/Themen/Wasser/Projekte/abgeschlossen/TZ/Namibia/groundwater_namibia.html

Coldrey, K. & Turpie, J. (2019). Climate Change Vulnerability and Adaptation Assessment for Namibia's Communal Conservancies. Anchor Environmental Consultants, Prepared for WWF Namibia.

Cunningham, P. (2014). Bush thickening in Namibia - a historical perspective. Journal - Namibia Scientific Society (ISSN 1018-7677), 164-185

Cunningham, P. & 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: 72-76

Dannhauser, C. & Jordaan, J. (2015). Practical Veld and Pasture Management for Farmers. Kejafa Knowledge Works, Krugersdorp, ISBN 978-0-620-61125-1

De-bushing Advisory Service (2021). Encroacher Bush Species of Namibia. Funded by the MEFT / GIZ Bush Control and Biomass Utilisation Project

De-bushing Advisory Service (2019). Bush Information System – A modern decision support tool to tackle bush encroachment in Namibia. Funded by the MEFT / GIZ Bush Control and Biomass Utilisation Project

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.

De Wet, M.J. (2015). Compendium of harvesting technologies for encroacher bush in Namibia. Commissioned by the MAWF / GIZ Support to De-bushing Project.

Eldridge, D. J., Wang, L. & Ruiz-Colmenero, M. (2015). Shrub encroachment alters the spatial patterns of infiltration. Ecohydrol., 8, pages 83– 93, doi: 10.1002/eco.1490

Espach, C., Lubbe, L.G. & Ganzin, N. (2006). Determining Grazing Capacity in Namibia: Approaches and Methodologies. Published by Agricola

FAO (2020). Terms and Definitions FRA 2020. Forest Resources Assessment Working paper 188

February, E.C., Cook, G.D. & Richards, A.E. (2013). Root dynamics influence tree–grass coexistence in an Australian savanna. Austral Ecol 38:66–75. https://doi.org/10.1111/j.1442-9993.2012.02376.x

February, E.C., Pausch, J. & Higgins, S.I. (2020). Major contribution of grass roots to soil carbon pools and CO_2 fluxes in a mesic savanna. Plant Soil https://doi.org/10.1007/s11104-020-04649-3

Filley, T.R., Boutton, T.W., Liao, J.D., Jastrow, J.D. & Gamblin, D.E. (2008). Chemical changes to nonaggregated particulate soil organic matter following grassland-to-woodland transition in a subtropical savanna. J. Geophys. Res. Biogeosci. 2008, 113, G03009.

Forest Stewardship Council (2020). The FSC National Forest Stewardship Standard for the Republic of Namibia FSC-STD-NAM-01-2019.

Global Infrastructure Hub (2020). Drones for Monitoring, Surveillance and Inspections. https://www.gihub.org/resources/showcase-projects/drones-for-monitoring-surveillance-inspection/

Government of Namibia (2021). Harambee Prosperity Plan II. http://hppii.gov.na/wp-content/uploads/2021/03/HPP2.pdf

Graw, V., Oldenburg, C. & Dubovyk, O. (2016). Bush Encroachment Mapping for Africa: Multi-scale analysis with remote sensing and GIS. ZEF – Discussion Papers on Development Policy No. 218, Center for Development Research, Bonn, July 2016, pp. 45.

Groengroeft, A., de Blécourt, M., Classen, N., Landschreiber, L. & Eschenbach, A. (2018). Acacia trees modify soil water dynamics and the potential groundwater recharge in savanna ecosystems. Climate change and adaptive land management in southern Africa - assessments, changes, challenges, and solutions. (ed. by R. Revermann, K.M. Krewenka, U. Schmiedel, J.M. Olwoch, J. Helmschrot and N. Jürgens), pp. 177 - 186. Klaus Hess Publishers, Göttingen & Windhoek

Hare, M.L., Xu, X., Wang, Y. & Gedda, A.L. (2020). The effects of bush control methods on encroaching woody plants in terms of die-off and survival in Borana rangelands, southern Ethiopia. Pastoralism 10, 16 (2020). https://doi.org/10.1186/s13570-020-00171-4

Hengari, S. (2018). Land Degradation Neutrality Pilot Project. A project of the Ministry of Environment and Tourism supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Herrick, J. (2018). Innovations and Solutions in Sustainability Science for Dryland Areas. Advancing Sustainability of US-Mexico Transboundary Drylands: A Binational Workshop San Luis Potosi MEXICO

Hodel, D. & Pittenger, D. (2002). Pittenger, Pruning. Page 321-332 in California Master Gardener Handbook. University of California, Division of Agriculture and Natural Resources.

Hudak, A., Wessman C. & Seastedt, T. (2003). Woody overstorey effects on soil carbon and nitrogen pools in South African savanna. Austral Ecol 28:173–181

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

Honsbein, D., Swart, W. & Lubbe, L. (2012). Evaluation of possible environmental effects of the generic aborocides tebuthiuron and bromacil under Namibian condition. Published for Meat Board of Namibia.

IPCC (2019). Working Group III - Mitigation of Climate Change. Retrieved from https://www.ipcc.ch/working-group/wg3/?idp=433

Joubert, D.F., Zimmermann, I., Nuulimba, N. & Pringle, H. (2013). Baseline Study of Bush Encroachment and Available Options for the Windhoek Green Belt Landscape. Ministry of Environment and Tourism with assistance from the Namibian Protected Landscape Conservation Area (NAMPLACE) Project

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

Joubert, D. & Zimmermann, I. (2017). Decision Support System on how to control bush thickening by Acacia mellifera in Namibian savanna rangelands. Funded by the MEFT / GIZ Bush Control and Biomass Utilisation Project

Lal, R. (2004). Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science Magazine Vol 304, pp. 1623 - 1627

Lesoli, M.S., Gxasheka, M., Solomon, T.B. & Moyo, B. (2013). Integrated Plant Invasion and Bush Encroachment Management on Southern African Rangelands, Herbicides - Current Research and Case Studies in Use, DOI: 10.5772/56182

Maillard, S. & Cheung, R. (2016). Unlocking the Market for Land Degradation Neutrality. UNCCD and Mirova.

Mangani T.R., Naude J.P., Sebitloane T.K.J., Kellner K. & Malan P.W. (2018). Brush Packing as a restoration methodology after bush control: Preliminary results. Poster and Presentation for the 6th Annual conference on "Transforming the Rehabilitation landscape" LaRSSA. School of Biological Sciences, Unit for Environmental Sciences and management, North-West University, South Africa, accessible at: https://www.bushmon.co.za/Downloads/list

Manjoro, M., Kakembo, V. & Rowntree K. M. (2012). Trends in soil erosion and woody shrub encroachment in Ngqushwa district, eastern cape province, South Africa, Environmental Management, Vol. 49, Issue 3, pp 570 - 579

Marselis, Y.M., van Dijk, S., Cary, A.G. & Chen, Y. (2015). Using LiDAR for forest and fuel structure mapping: options, benefits, requirements and costs. Bushfire & Natural Hazards CRC, Australia.

MAWF & MET (2017). Forestry and Environmental Authorisations Process for Bush Harvesting Projects. 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

Mendelsohn, J., Jarvis, A., Roberts, C. & Robertson, T. (2002). Atlas of Namibia. A Portrait of the Land and Its People.

Meyer, N. (2020). Evaluation of Brush Packing Methods on different Semi-Arid Savanna Soil Types and Properties. North-West University, South Africa, accessible at: https://www.bushmon.co.za/Downloads/list

Meyers, D., Bohorquez, J., Cumming, T., Emerton, L., Heuvel, O.v.d., Riva, M. & Victurine, R. (2020). Conservation Finance: A Framework. Conservation Finance Alliance, www.cfalliance.org

Ministry of Environment and Tourism (2014a). Namibia's Second National Biodiversity Strategy and Action Plan 2013 – 2022.

Ministry of Environment and Tourism (2014b). Third National Action Programme for Namibia to Implement the United Nations Convention to Combat Desertification 2014 – 2024.

Ministry of Environment and Tourism (2015). Land Degradation Neutrality National Report 2015.

Ministry of Environment and Tourism (2018). National GHG Inventory Report NIR3 1994 – 2014.

Ministry of Environment and Tourism (2020a). Fourth National Communication to the United Nation Framework Convention on Climate Change.

Ministry of Environment and Tourism (2020b). Fifth National GHG Inventory Report.

Ministry of Environment and Tourism (2021). Namibia's Updated Nationally Determined Contribution to the United Nations Framework Convention on Climate Change.

Mudaliar, A. and Dithrich, H. (2019). Sizing the Impact investing Market, Global Impact Investing Network 2019.

Mungkunkamchao, T., Kesmala, T., Pimratch, S., Toomsan, B. & Jothityangkoon, D. (2013). Wood vinegar and fermented bioextracts: Natural products to enhance growth and yield of tomato (Solanum lycopersicum L.). Scientia Horticulturae, Volume 154, Pages 66-72, ISSN 0304-4238, https://doi.org/10.1016/j.scienta.2013.02.020.

Nepolo, E. and Mapaure, I. (2012). Short-Term Influence of Fire on Herbaceous Composition, Diversity and Grass Biomass Production in Semi-Arid Savanna Woodland in Windhoek, Namibia. International Journal of Ecosystem. 2. 154-160. 10.5923/j.ije.20120206.02.

Nott, C., Boys, J.M. & Nzehengwa, J. (2019). Reviving Namibia's Livestock Industry - Regenerative Livestock Production – Trends, Key Profit Drivers, Case Studies & Recommendations. Based on Namibia Rangeland Management Policy (NRMP): A 2019 Edition

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, DOI: 10.2989/10220119.2014.939996

Orr, B.J., Cowie, A.L., Castillo Sanchez, V.M., Chasek, P., Crossman, N.D., Erlewein, A., Louwagie, G., Maron, M., Metternicht, G.I., Minelli, S., Tengberg, A.E., Walter, S. & Welton, S. (2017). Scientific Conceptual Framework for Land Degradation Neutrality. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.

Perche, J. and Stoldt, M. (2020). Finance Mechanism Review to Fund Post-Harvest Treatment Measures. Commissioned by the MEFT / GIZ BMCC II Project.

Phillips-Mao, L. (2017). Restoring Your Woody-Invaded Prairie to Conservation Prairie, The Nature Conservancy 2017.

Porensky, L.M. & Veblen, K.E. (2012). Grasses and browsers reinforce landscape heterogeneity by excluding trees from ecosystem hotspots. Oecologia 168, 749–759 (2012). https://doi.org/10.1007/s00442-011-2123-9

Reid, H., Sahlén, L., Stage, J. & Macgregor, J. (2008). Climate change impacts on Namibia's natural resources and economy. Climate Policy. 8. 452-466. 10.3763/cpol.2008.0521.

Rodale Institute (2015). Regenerative Organic Agriculture and Climate Change: A Down-to-Earth Solution to Global Warming. https://rodaleinstitute.org/why-organic/organic-basics/regenerative-organic-agriculture/

Rothauge, A. (2014). Baseline Assessment for the De-bushing Programme in Namibia. Commissioned by the MAWF / GIZ Support to De-bushing Project

Rothauge, A. (2019). Scoping Report - Developing an Aftercare Stewardship Programme for Bush Control and Biomass Utilisation Projects. Commissioned by the MAWF / GIZ Bush Control and Biomass Utilisation Project

Sadakichi, K. & Hirowaka, T. (n.d.) Wood Vinegar and Biochar in Agriculture - How to Improve Crop Quality While Reducing Dependence on Agricultural Chemicals.

SAIEA (2016). Strategic Environmental Assessment of large-scale bush thinning and value addition activities in Namibia. Final Report, Southern African Institute for environmental assessment. Commissioned by the MEFT / GIZ Bush Control and Biomass Utilisation Project

Saunders, O. (2014). Guide to Using Wood Ash as an Agricultural Soil Amendment, The University of New Hampshire Cooperative Extension.

Schwarz, K., Finckh, M., & Stolter, C. (2018). Influence of differently managed bush encroached sites on the large herbivore distribution in the Namibian Savannah. Afr J Ecol. 2018; 56: 290–300. https://doi.org/10.1111/aje.12451

Sebitloane, T.K.J, Kellner, K., Malan, P.W. & Coetzee H. (n.d.). Restoration after the control of bush encroachment and the socio-economic impacts on rural communities in Taung, North West Province, South Africa, Poster, North-West University, accessible at: https://www.bushmon.co.za/Downloads/list

Seebauer, M., Pinkwart, A., Schwarz, B. & Hartz, C. (2019). Greenhouse Gas Assessment of Bush Control and Biomass Utilisation in Namibia. Commissioned by MAWF / GIZ Bush Control and Biomass Utilisation Project

Sheuyange, A., Oba, G. & Weladji, R.B. (2005). Effects of anthropogenic fire history on savanna vegetation in northeastern Namibia, Journal of Environmental Management. Volume 75, Issue 3, Pages 189-198, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2004.11.004.

Smit, G.N. (n.d.) Thickening of woody plants in savanna: An approach to understanding and managing the problem.

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, Volume 71, Issue 2, Pages 179-191, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2004.02.005.

Smit, G.N. (2005). Tree thinning as an option to increase herbaceous yield of an encroached semi-arid savanna in South Africa. BMC ecology. 5. 4. 10.1186/1472-6785-5-4.

Smit, G.M., Schneider, M.B. & Van Eck, J. (2015). Detailed assessment of the biomass resource and potential yield in a selected bush encroached area of Namibia. Commissioned by the MAWF / GIZ Support to De-bushing Project

Stoldt, M. & Perche, J. (2020). State of Knowledge on Post-Harvest Treatments. Commissioned by the MEFT / GIZ BMCC II Project.

Tews, J., Blaum, N. & Jeltsch, F. (2004). Structural and Animal Species Diversity in Arid and Semi-arid Savannas of the Southern Kalahari. Annals of arid zone. 42. 1-13.

Trede, R. & Patt, R. (2015). Value Added End-Use Opportunities for Namibian Encroacher Bush. Commissioned by the MAWF/GIZ Support to De-bushing Project

Twidwell, D. & Fogarty, D. (2020). A Guide to Reducing Risk and Vulnerability to Woody Encroachment in Rangelands. https://agronomy.unl.edu/faculty/Twidwell/WPE-vulnerability-guide-preprint.pdf

UNCCD (n.d). An Impact Investment Fund for Land Degradation Neutrality. UNCCD Website. https://www.unccd.int/actions/impact-investment-fund-land-degradation-neutrality

UNDP (2016). a. Payments of Ecosystem Services. Financing Solutions for Sustainable Development. http://www.undp.org/content/dam/sdfinance/doc/Payments%20for%20Ecosystem%20Services%20_%20UNDP.pdf

UNDP (2016). b. Environmental Trust Funds. Financing Solutions for Sustainable Development. https://www.sdfinance.undp.org/content/sdfinance/en/home/solutions/environmental-trust-funds.html

UNIDO (2019). Strategic Action Plan for Sustainable Bush Value Chains in Namibia. https://www.unido.org/sites/default/files/files/2020-02/Namibia_v_2.20-spreads%20%281%29.pdf

Van der Waal, C. & Stoldt, M. (2020). Environmental Assessment of Post-Harvest Treatment Measures. Commissioned by the MEFT / GIZ BMCC II Project.

Van Oudtshoorn, F. (2015) Veld Management Principles & Practices, Briza Publications, Pretoria, ISB N 978-1-920217-29-7

Wigley, B.J., Augustine, D.J, Coetsee, C., Ratnam, J. & Sankaran, M. (2020). Grasses continue to trump trees at soil carbon sequestration following herbivore exclusion in a semi-arid African savanna. Ecology

Wiklund, J. (2017). Effects of wood ash on soil fertility and plant performance in southwestern Kenya, Swedish. University of Agricultural Sciences, Faculty of Natural Resources and Agricultural Sciences, Department of Soil and Environment

Wingate, V.R., Phinn, S.R., Kuhn, N. & Scarth, P. (2018). Estimating aboveground woody biomass change in Kalahari woodland: combining field, radar and optical datasets. https://www.cabdirect.org/cabdirect/abstract/20183181812

Wingate, V.R., Phinn, S.R., Kuhn, N., Bloemertz, L. & Dhanjal-Adams, K.L. (2016). Mapping Decadal Land Cover Changes in the Woodlands of Northeastern Namibia from 1975 to 2014 Using the Landsat Satellite Archived Data. Remote Sens. 2016, 8, 681; doi:10.3390/rs8080681

Woods, S.R., Fehmi, J.S. & Backer, D.M. (2012). An assessment of revegetation treatments following removal of invasive Pennisetum ciliare (buffelgrass). Journal of Arid Environments, Volume 87, Pages 168-175, ISSN 0140-1963, https://doi.org/10.1016/j.jaridenv.2012.06.009.

World Bank Group (2016). Biodiversity Offsets: A User Guide. https://www.cbd.int/financial/doc/wb-offsetguide2016.pdf

Zimmermann, I., Nghikembua, M.T., Shipingana, D., Aron, T., Groves, D. & Marker, L. (2017). The influence of two levels of de-bushing in Namibia's Thornbush Savanna on overall soil fertility, measured through bioassays.

Zimmermann, I., Lindeque, C. & Schimetka, L. (2020). Biochar from Namibian Encroacher Bush. Prepared by MEFT / GIZ Bush Control and Biomass Utilisation project.

8 Annex

A1 Effects of Bush Thickening in Namibia

Negative Impacts of Woody Encroachment

Carbon Sequestration

Woody encroachment redistributes carbon among key terrestrial pools. While arid areas are more likely to become net sources of carbon, areas with higher rainfall are more likely to become net sinks (Archer et al. 2017).

The dense bush in Namibia stores considerable CO_2. The carbon density of bush follows an S-shape: In the beginning, encroacher bushes take up a lot of carbon before uptakes plateau and reach zero. A study by Scholes et al. 2005 suggests that many Namibian sites have reached their peak carbon sequestration, but that there is considerable room for expansion into other areas. The high uptake of carbon is likely to make Namibia a net sink for greenhouse gases, although it is considered unsustainable due to the impacts of bush encroachment outlined in this section (Scholes et al. 2005).

Savannas store almost double the soil organic carbon stored in biomass. If bush biomass is fully matured, it reaches an equilibrium where changes in carbon are mainly caused by new encroachment in other areas. Soil organic carbon decomposes slowly. It can take several decades (Seebauer et al. 2019).

Hydrology

Woody encroachment can influence runoff, precipitation, deep drainage and evapotranspiration, and thus all components of the water budget. Woody plants use water from deeper soil layers and have long periods of transpiration, which reduces underground water levels – critical sources of water in Namibia. Woody plants have a higher air turbulence and lower albedo which increases their potential evapotranspiration. They also have a higher canopy interception of rain. The impact of woody encroachment is greatest when the potential evapotranspiration equals total precipitation (Archer et al. 2017).

A study conducted in Australia suggests that bush encroachment can influence both infiltration and runoff, which are key processes responsible for the distribution of rainwater in drylands (Eldridge et al. 2014). Runoff can be influenced by changes in the soil infiltration rate caused by woody encroachment (Archer et al. 2017). The impact of bush encroachment on the hydrology will depend on the proportion of shrub and grass canopy and the interspace. Bush encroachment impacted the amount and spatial distribution of infiltration and un-vegetated interspace arrangements, thus impacting the water balance of the ecosystem (Eldridge et al. 2015).

Biodiversity

Woody encroachment can be transformative, shifting landscapes from grassland to shrub or tree savannas and these savannas to woodlands or shrublands. As a result of woody encroachment, grassland ecosystems are endangered in many parts of the world. This shift also causes species adapted to grasslands to be replaced by species adapted to woodlands or shrublands. Although this may increase the overall diversity of species, it may displace species endemic to savanna or grassland ecosystems (Archer et al. 2017). The most damaging species are those that transform ecosystems by changing the disturbance regime: They often use large amounts of resources such as light, water and nutrients and can change the food web and habitats, thus often reducing the abundance of other plants (Lesoli et al. 2013).

The selection of habitats by herbivores is influenced by forage quality and availability as well as habitat structure. This can be impacted by bush encroachment (Schwartz et al. 2017). Woody encroachment can create monocultures, decreasing the overall diversity of plant species (Archer et al. 2017). Generally, woody encroachers can impact functional groups, species abundance and evenness of the herbaceous layer even if there are no clear changes in species richness. Changes in the species composition of vegetation can have considerable impacts on ecosystem processes including trophic pyramids, primary production and nutrient cycling. These changes in vegetation can reduce the quality and quantity of habitats for wildlife. The distribution and abundance of many grassland species has declined throughout the world. Some taxa are more sensitive to structural changes than others (Archer et al. 2017).

Different studies elude on the detrimental impact of woody encroachment at higher densities on the abundance of small carnivore species native to the Kalahari (Blaum et al. 2007). Larger bush encroached areas also have a lower diversity and abundance of mammals and birds (Blaum et al. 2009). In a South African study, bird species richness was shown to peak at intermediate bush densities. In areas with denser thickets, some open-habitat species disappeared (Sirami et al. 2009). In a Namibian study accounting for the entire aridity gradient, bird species richness was lower in bush encroached thickets than grassy habitats (Hoffman et al. 2010). In central Namibia, lizard species richness declined in dense bush habitats relative to open habitat. Only one species was observed in larger numbers in bush encroached areas (Meik et al. 2002). Results from the BIOTA long-term studies show that although the responses of animal groups vary between taxa, two major patterns are evident. Species richness of grasshoppers, reptiles and rodents declined with shrub cover while spiders, beetles, and carnivores exhibited bell-shaped responses to shrub cover. Species richness was maximised at shrub cover values between 12 and 18% (Hoffman et al 2010 p.49).

Apart from having detrimental effects on grazers due to the suppression of grasses, very high bush densities can also have detrimental effects on browsers (Smit 2004). Woody encroachment can reduce the reproductive success and survival, change predation patterns, encourage parasitism and alter the availability, type and abundance of food resources for both grazers and browsers (Archer et al. 2017).

Soils

Soil organic matter and soil organic carbon bind nutrients and water and are thus closely linked to soil fertility. Woody encroachment and the resulting increases in biomass can change soil microbial communities and slow decomposition ratios and thus soil fertility. Bare areas between bushes in encroached landscapes can also lead to soil erosion created by wind (Seebauer et al. 2019).

Economic and Social Impact

Many savanna ecosystems have limited water availability and woody thickening is considered a key threat to herbaceous plants. The grazing capacity in many Southern African countries has considerably declined, making livestock production economically unviable in many areas (Smit 2004).

Bush encroachment makes land inaccessible for livestock and has negative effects on the use of rangelands. The competition for light, nutrients and water by woody plants reduces the capacity of rangelands. The degradation of rangelands can have considerable impacts on food security and poverty levels (Lesoli et al. 2013).

Apart from the potential negative impact on the diversity of wildlife and plants, bush encroached landscapes are often less aesthetically pleasing and have a reduced aesthetic value for tourism (Lesoli et al. 2013).

Positive Effects of Woody Encroachment

Woody plants can also have a positive impact on the ecosystem. They create unique and diverse habitats and provide browse for livestock and wildlife (Smit 2004). Open savanna landscapes with islands of dense thickets may have the highest overall biodiversity. Namibia generally has soils with low fertility and low soil organic carbon, limiting vegetation growth and agriculture (Hengari 2018). Trees can have a positive impact by enriching the soil under their canopy. Some desirable grasses are positively associated with tree canopies and they provide an important sub-habitat for different species (Smit 2005). However, trees in lower densities often have better browse, and leaves can maintain younger phenological states for a longer time (Smit 2004).

The nutrients available to plants are higher in encroached landscapes due to the nitrogen fixing ability of bush with their deep roots. Soil organic matter and soil organic carbon are created through decomposition of organic matter. A lack of these organic inputs from wood, leaves and roots can considerably reduce soil fertility (Seebauer et al. 2019).

Soil hydraulic properties affect the water holding capacity of the soil and moisture available to plants. Infiltration of rainwater is highest close to the canopies of woody plants, due to the plant litter underneath the canopy creating higher levels of organic matter and nutrients. In addition, the extensive distribution of roots creates macropores, which have a positive effect on infiltration (Eldridge et al. 2015).

Woody encroachment can increase primary production and carbon sequestration in some cases and promote land uses which use the woody biomass for commercial purposes. The woody biomass may thus become an economic opportunity, diversifying the economy and generating income (Archer et al. 2017).

A2 Bush Value Chains

Charcoal

Currently, charcoal is the largest value chain in Namibia using, processing and exporting bush biomass. Demand has exceeded supply for years and the demand is expected to increase. There are about 1100 active producers and 8,500 people directly and indirectly employed in the charcoal sector. Of the annual production of >200,000 tonnes, 99% is exported. Charcoal is produced from solid wood, preferably 10 to 18 cm in diameter. Heavy hardwoods result in the best charcoal *(ibid.)*.

Opportunities

- Mixed species suitable for high quality charcoal
- About 50% of producers previously disadvantaged
- Simple technologies provided by local SMEs
- Labour intensive production
- Low investment and no additional inputs
- World market increasingly undersupplied
- Strong position of Namibia as 6th largest exporter
- Suitable legislative framework in place *(ibid.)*

Challenges / risks

- Lack of control and some illegal harvesting
- Lack of regulations for encroacher bush use
- Limited capacity and productivity of the industry
- Lack of business orientation and quality consciousness
- Due to the hard work required, problems to mobilise workers
- Unsatisfactory working conditions
- Long marketing chains (often via RSA) *(ibid.)*

Biochar

Biochar has the potential to become an important product for agricultural use in Namibia and for commercialisation. It can be used for soil enhancement as it increases the soil's water and nutrient holding capacity and also as an additive for livestock nutrition in order to improve the animal's health (Zimmermann et al. 2020).

Opportunities

- Simple on-farm machinery
- Great local agricultural potential
- Increasing international demand
- Applies to recently unutilised parts of the bush
- Supports holistic rangeland management *(ibid.)*

Challenges / risks

- Lack of existing off-take opportunities
- Limited experience with local application
- No regulative framework in place *(ibid.)*

Wood Chips & Pellets

The large demand for biofuel in industrialised countries can often not be satisfied due to limited resources. Both pellets and chips can be used for heat and power generation. Pellets are not yet produced in Namibia. Biofuels could be used to reduce Namibia's energy dependency on fossil fuel imports *(ibid.)*.

Opportunities	Challenges / risks
• Local experience • Existing currently unsatisfied domestic demand • Unsatisfied demand in several industrialised countries • No quality requirements for woodchips in Europe • Mixed species and finer branches unsuitable for charcoal can be used • Flexible use of equipment (mobile or mechanised) *(ibid.)*	• Technical problems due to the hardness and high sand content of indigenous wood • Employment creation is limited • Wood chips are only competitive if transport distances are short • Wood chips provide limited value addition • No local demand for pellets and hardly any demand in neighbouring countries *(ibid.)*

Firewood

Firewood is often used for cooking and heating. Around 100,000 households are involved in firewood production, mainly from dead and dry wood, for own consumption and sale in informal markets. Firewood is sold by numerous informal producers in communal areas and by some commercial farmers. It is collected manually and cut into desired lengths. Only a small portion of the firewood is from encroacher bush, mainly as by-product of bush thinning on commercial farms (Trede & Pratt 2015).

Opportunities	Challenges / risks
• High acceptance as cooking and heating material • Most producers stem from previously disadvantaged backgrounds • Labour-intensive; no skills required • Very low investment • No additional production inputs (e.g. water, electricity) required • High local demand • High value addition if marketed in urban centres *(ibid.)*	• Unsustainable harvesting of live wood can result in the depletion of scarce resources. • No formal value chains • Harvesting of protected species or in environmentally sensitive areas • Limited value addition and income generation for producers • High prices for end-consumers • Low energy efficiency *(ibid.)*

Animal Feed

Production of animal feed from encroacher bushes could address major challenges around the scarcity of feed, caused by overgrazing and droughts. The edible parts of the biomass must be milled and mixed with different additives. Pelleting might improve the suitability as commercial product *(ibid.)*.

Opportunities	Challenges / risks
• High local demand if prices are competitive • In contrast to other bush products, small twigs, leaves, etc. are used • Substitute for imported feed • Decentralised production, e.g. in communal areas *(ibid.)*	• Only selected species are edible • Wood component in feed is 10% - 80% • Export prospects are not promising • Local demand is highly variable depending on the annual rainfall and price of the bush-based fodder *(ibid.)*

Poles

Poles for the construction of traditional houses and fencing are one of the main biomass products from Namibian bush species. They are predominantly used by communal and commercial farmers and sold informally. Formal sales are very limited. The only known commercial outlet is Pupkewitz Megabuild in Katutura, Windhoek. In the global formal trade the market requires standardised straight length and diameter, and poles are thus mainly from man-made forests *(ibid.)*.

Opportunities	Challenges / risks
• High and stable demand for poles in Namibia • The local market share can be considerably increased if local entrepreneurs start formal pole businesses • Resources available at low cost • Some species are resistant against decay and termites • Limited skills required • Very low investment • Potential of income generation for disadvantaged people • Few additional inputs required *(ibid.)*	• Namibian bush normally does not grow straight, and mixing different species requires sorting • Competition from imported wooden poles and poles made from other materials • Competition with own-use and free access • Hardly any formal value chain in place and unreliable supply • Production not in line with demand • Harvesting in protected areas and in environmentally sensitive areas *(ibid.)*

Wood-Cement (bonded bricks or boards)

Wood particles can be used as an organic aggregate in the concrete mixture. The cement acts as wood particle binder. This mixture is suitable to produce solid or hollow bricks, panels and prefabricated walls for outdoor construction material, partitioning, ceilings, acoustics applications, wall cladding, roofing, shuttering and more. The products are commonly accepted by local and international markets due to their excellent properties including insulating capability and non-combustibility. They are hardly known in Namibia but are used in other countries *(ibid.)*.

Opportunities	Challenges / risks

Opportunities

- Increasing demand for environmentally friendly products in industrialised countries.
- Excellent properties
- Easy to assemble with normal woodworking tools
- Can substitute other imported building materials
- Main input materials are available locally
- Technologies available
- Competitive costs compared with other building materials
- Employment creation *(ibid.)*

Challenges / risks

- The normal resource basis are softwoods; the properties of Namibian hardwoods are not known
- Probably not all species can be used
- Bark hampers the production and it must be tested if bark content is acceptable
- High investment
- Most staff should be semi-skilled and skilled *(ibid.)*.

Wood-Plastic Composites

The use of wood and plastic is relatively new even in industrialised countries. The composites are made from a mixture of saw dust and polypropylene or polyethylene. Market products contain at least 30% plastics. In Namibia, WPCs might be an interesting value chain to manufacture products for indoor construction, furniture production and agriculture. Mixed species were suitable as input material in Namibian trials. The entire bush can be used, including leaves *(ibid.)*.

Opportunities	Challenges / risks

Opportunities

- Excellent properties, e.g. water resistance, shrinking, biodegradation
- Technologies internationally available
- Considerable knowledge and experience in Namibia's polymer industry
- Large, variable product range
- Could replace comparable materials that are currently imported
- High value addition
- Flexible investment *(ibid.)*

Challenges / risks

- Plastics must be imported
- Product specific moulds are fairly expensive
- Considerable market research required to determine optimal product range
- Products relatively expensive, i.e. marketing efforts required to introduce "new" products in Namibia *(ibid.)*

Medium-density Fibreboards

MDFs are the second most important panels produced worldwide. They have a smooth, homogenous structure which is easy to lacquer, laminate and print. The boards are mainly used for furniture production, as building boards and laminates for furniture and flooring. Although there is no production in Namibia, some tests have been undertaken with thin branches and production may be possible *(ibid.)*.

Opportunities

- Known and applied technologies available
- Selected encroacher species suitable for production, including small branches
- Employment creation
- High demand in other African countries
- MDFs could replace comparable materials that are currently imported
- High value addition when used in the furniture industry *(ibid.)*

Challenges / risks

- Preferred raw material for fibre boards is softwood; Namibian hardwoods can be used in a mixture and require more intensive gluing which may affect the dimension stability of the board
- The high density of the wood can make production more expensive in international markets
- Bark reduces the quality of the boards *(ibid.)*

Some other value chains with undetermined demand, include:

- **Traditional Medicine:** In Namibia, various plants are used for traditional medicine, which plays an important role both nationally and internationally. Namibia currently only exports devil's claw. Collection, processing and marketing of other traditional medicinal plants from bush with high value addition could be promising for European and North American markets but require considerable research e.g. Baphia massaiensis *(ibid.)*.
- **Parquet:** Parquet flooring is popular in Europe, North America and higher income groups in Namibia. Parquet production requires a high-density wood, which is fulfilled by Namibian bush species *(ibid.)*.
- **Wooden Frames & Kitchen Boards:** Both can be produced from small strips of wood that are sawn together. They are currently exclusively imported although local production is feasible *(ibid.)*.
- **Domestic Tools & Carving:** Tools like cooking sticks and axe handles are produced manually in rural areas for local use. Good quality traditional walking sticks are produced for both local people and as souvenirs for tourists. However, most domestic tools are imported *(ibid.)*. Carving is a tradition in several parts of Namibia, mainly catering for the tourism market *(ibid.)*.
- **Wood Glue:** Glue can be produced from wood components e.g. from tannins. Research is undertaken in Namibia to develop a natural binder from native bush species *(ibid.)*.
- **Smoking /Aromatic Material:** A small local market is using wood to aromatise meat or fish. The wood is mostly imported and marketed at high prices. By-products from wood chipping, sawing or production of sticks and handles could be used *(ibid.)*.
- **Wood Acid** is a side-product of charcoal production when the smoke is distilled and left to stand for 3 months to naturally purify. It is used for various purposes including as animal feed supplement, odour remover, insect repellent as well as foliar and soil fertiliser (Mungkunkamchao et al. 2013).

A3 Harvesting and Post-Harvesting Methods

Preventative Measures to Avoid Encroachment

Rangelands are at risk of bush encroachment if a considerable number of seed is available, or seedlings have started to establish themselves. Monitoring is required to assess the presence of seeds and seedlings, proximity to seed sources and how quickly encroachment in surrounding areas is expanding. To ensure an intact area does not become encroached, seed contamination from surrounding areas should be minimised, existing seed banks must be controlled and seedlings must be removed before reaching maturity (Twidwell & Fogerty 2020).

Fire

Fire is part of savanna ecosystems. Fire is not suitable for bush control in areas with a very high bush density, due to limited fuel load for high intensity fires. However, in less densely thickened areas, it can suppress sapling establishment as well as growth rate and change the height strata of bush to make it available for browsers (De Klerk 2004). The exclusion of fire is one of the drivers of bush encroachment. Controlled burning can be a preventative measure (ibid). The use of fire is regulated by the Forest Act and Regulations. A Fire Management Strategy has been developed for Protected Areas, but not for any other area.

Biological Control

Browsing may be a viable option as a preventive strategy in areas with low bush densities or where the livestock system can be adapted to the vegetation and the dense bush is palatable (De Klerk 2004). Browsing can also control woody plants in the recruitment stage (Twidwell & Fogerty 2020).

Manual Control

Seedlings and small trees can also be manually removed or hayed (Twidwell & Fogerty 2020).

Bush Control Methods for Initial Thinning Operations

Conventional Medium to Large-Scale Mechanical Control

Overview

Conventional bush control techniques often use heavy machinery to thin or clear the bush without harvesting biomass. This involves the use of bush rollers on frontend loaders, mulching machines mounted to excavators, bulldozers, tractors, or graders with blades as well as chains mounted between two tractors or bulldozers (De Wet 2015). Depending on the equipment used, the woody biomass can still be used for different value chains (Van Oudtshoorn 2015).

Impacts

Due to the heavy machinery involved, soil surface is disturbed considerably and re-encroachment can cause areas to thicken to even higher densities than before within 5 – 6 years (De Klerk 2004, De Wet 2015). This is exacerbated if land is clear cut, due to the considerable seedling establishment after the competitive release from larger bushes.

Regrowth

The considerable disturbance can encourage the establishment of bush (Smit n.d.) by preparing a seedbed with little initial herbaceous competition. When uprooting, some roots can withstand, re-sprout heavily and often change their form from single- to multi-stemmed (Welch n.d.). Since most problem species coppice strongly, at least 90% of the thinned plants will regrow. *Dichrostachys cinerea* often has a 100% regrowth. If bushes are removed 10 cm below the soil surface, they often do not show any regrowth – with the exception of *Dichrostachys cinerea*. Re-seeding with grasses may be necessary as a follow-up treatment (De Klerk 2004).

Mitigation & Recommendations

The use of machinery can help to "open up" areas of very thick bush. However, given the strong regrowth after mechanical control and the often poor establishment of natural grasses, bush control for restoration and sustainable use must use post-harvest treatment measures (De Klerk 2004) to control regrowth and rehabilitate the soil. In addition, some mitigation or preventative measures can include:

- If a rehabilitation / restoration objective is pursued, some of the harvested bush should be left on the land to enhance soil fertility (Joubert & Zimmermann 2017).
- Complete clearing must be avoided at all costs to mitigate against the long-term loss of soil nutrients (De Klerk 2004).
- Harvesting could be done along contour strips. Un-cleared strips create windbreaks and fertilise treated areas (Joubert & Zimmermann 2017).

For medium- to large-scale mechanised harvesting, a formal Environmental Impact Assessment and Environmental Clearance Certificate is required as well as a Forest Management Plan required by the Forest Act.

Heavily Mechanised Bush Thinning Control

Overview

Highly mechanised thinning of bush uses skidsteer harvesters with horizontal rotary cutters or sawblades, three-wheel loaders with a buncher and hydraulic cutters, hydraulic grabs and or buncher with blade cutter, hydraulic grab and tree pullers as well as combined harvesters and grinders on tracks with shuttle buckets (De Wet 2015).

Impacts

Heavily mechanised thinning can be very selective and thus has a lower ecological impact than conventional mechanical control. Soil and wildlife can still be disturbed by the machinery, but to a lesser extent.

Regrowth

Since most problem species coppice strongly, at least 90% of the thinned plants will regrow. *Dichrostachys cinerea* often has a 100% regrowth. If bushes are removed 10cm below the soil surface, they often do not show any regrowth – with the exception of *Dichrostachys cinerea* (De Klerk 2004). However, while many conventional methods can encourage seed germination by dispersing the seeds, this can be reduced with highly mechanised methods.

Mitigation & Recommendations

The use of machinery can help to "open up" areas of very thick bush. However, given the strong regrowth after mechanical control and the often poor establishment of natural grasses, bush thinning for restoration and sustainable use must use post-harvest treatment measures (De Klerk 2004) to control regrowth and rehabilitate the soil. Harvesting should be selective, leaving bushes of different sizes and densities to create a diverse landscape. Harvesting can be done along contour strips. Un-cleared strips create windbreaks and fertilise treated areas (Joubert & Zimmermann 2017).

Manual and Semi-Mechanised Control

Overview

Manual methods are mainly used to control woody plants in small areas. These measures are very selective and minimise damage for desirable plants but are time and labour intensive and must be conducted several times to ensure minimum re-thickening (Lesoli et al. 2013). Manual thinning uses axes, pangas, pruning tools or saws, handheld chainsaws, multi-circular saws, tractor drawn slashers and trolleys with type or circular cutters (De Wet 2015).

Impact

Manual harvesting does not have considerable negative side effects if done selectively and correctly. The re-growth tends to be multi-stemmed which can exacerbate future problems (Joubert & Zimmermann 2017). The manual control of bush can provide considerable job opportunities and the wood can be used for different value chains and for the post-harvest treatment of the land (Van Oudtshoorn 2015).

Manual control of bush is very labour intensive and very hard work and may thus only be viable for smaller areas (Van Oudtshoorn 2015, Lesoli et al. 2013). Since workers are often paid based on the weight of harvested biomass, they are incentivised to cut large trees and bushes – although these should be maintained and smaller plants should be harvested. This may cause invasion by other low biomass problem species (*Grewia flava* and *G. flavescens*) forming dense, impenetrable clumps (Smit et al. 2015).

Regrowth

Since most problem species coppice strongly, at least 90% of the thinned plants will regrow (De Klerk 2004) if an area is cleared. With selective harvesting, the percentage is much lower. *Dichrostachys cinerea* often has a 100% regrowth. If bushes are removed 10 cm below the soil surface, they often do not show any regrowth – with the exception of *Dichrostachys cinerea* (De Klerk 2004).

Mitigation

Manual methods can be used to selectively thin bush in smaller areas and harvest biomass for sustainable use. Bush control for rehabilitation / restoration and sustainable use must use post-harvest treatment measures (De Klerk 2004) to control regrowth and rehabilitate the soil. In addition, some mitigation or preventative measures can include:

- Large trees should be left in the landscape, which must be monitored.
- Harvesting should be done along contour strips. Un-cleared strips create windbreaks and fertilise treated areas (Joubert & Zimmermann 2017).
- There could also be some inter-seeding with desired perennial grasses to enhance long-term productivity (ibid).
- Workers should be carefully trained and monitored to ensure protected species are not harvested and bushes / trees of various strata remain on the land.

Chemical Control

Overview

Arboricides have different chemical properties which make them applicable for different soils, climates and application options. They have different effects on the environment (Lesoli et al. 2013).

Soil Applied Arboricides are applied to the soil and absorbed by the roots. They are mostly based on bromacil, tebuthiuron or ethidimuron. Concentrations between 20% and 70% are available in the form of granules, liquid or a wetable powder (ibid). They are mainly applied by hand to the soil around the stem of the plant. Water infiltrating the soil dissolves the chemical and transports it to the root zone (Van Oudtshoorn 2015). Some can be used for aerial application (Lesoli et al. 2013).

Plant Applied Arboricides are sprayed onto the plant and absorbed by the foliage or other parts such as stems. They are mainly based on picloram, 2.4-D and 2.4.5-T (Lesoli et al. 2013). They can be applied selectively by hand or unselectively through aerial spraying (Van Oudtshoorn 2015). This includes Basal Stem Application, where the lower 30cm of the stem and uncovered roots are treated, and Frill Application, where the chemicals are applied to cuts created by an axe (ibid).

Impacts

Currently, the impact on microorganisms is unknown, but arboricides can be toxic to insects and rabbits. The accumulation of arboricides can also create unwanted ecosystem impacts (Joubert & Zimmermann 2017). Leaching through the soil can contaminate groundwater (Lesoli et al. 2013).

Aerial application is unselective and prohibited by the Forest Regulations of 2015.

The incorrect use of chemicals can have considerable offsite impacts caused by runoff, leaching into groundwater and spray drift (Honsbein et al. 2012).

Regrowth

Regrowth is limited if the correct doses are applied (Joubert & Zimmermann 2017). Seedling regeneration can be suppressed for up to 5 years, due to the residual effects of chemicals (De Klerk 2004). Without residual effects, seedling establishment can be considerable due to released competition.

Mitigation & Recommendations

Chemical control can be expensive (De Klerk 2004) and can have considerable detrimental impacts if incorrectly used (Honsbein et al. 2012). As a result, it should be used as a last resort and only under specific considerations:

- At very high bush densities where other methods are not viable e.g. not enough fuel load to support a fire, bush heights out of the range of browsers, severely restricted access for animals, the species are unpalatable, or browsers cannot be used for other reasons (De Klerk 2004).
- When arboricides are very selective and do not affect palatable species, such as desired fodder bushes and trees (De Klerk 2004). Due to their unselective nature, soil-applied arboricides should not be used (Smit et al. 2015).
- Post-harvest treatment programmes are vital to avoid worse problems (De Klerk 2004).

Land should not be cleared, due to the long-term impacts on soil nutrients (ibid), and selective methods should be used. Harvesting along contour lines to regenerate water and nutrient cycling can mitigate some of the negative impacts (Joubert & Zimmermann 2017). Chemicals should not be used within 100 m of pans, fountains, perennial or ephemeral rivers, rivulets and drainage lines (FSC 2020).

Ideally, if arboricides are used they should be used in a year with low seed production to limit increased seedling establishment after thinning (Joubert & Zimmermann 2017).

Soil Applied Herbicides: The amount required depends on the pH, organic matter and clay content of the soil. They remain in the soil and are activated by the first rains, which dissolves the active ingredient until it can be taken up by the roots of the woody plants (Lesoli et al. 2013). When the clay content of the soil exceeds 30%, this form of chemical control is considered too expensive. To ensure non-targeted species are not killed, the distance between targeted and untargeted plants should be more than double the height of the non-targeted plant (Van Oudtshoorn 2015).

Plant Applied Herbicides – Foliar Spraying: Should only be considered when the plants are smaller than 1.5 – 2 m. Spraying during strong winds must be avoided. Follow-ups are necessary to treat coppicing plants (Van Oudtshoorn 2015).

The FSC encourages the use of other silvicultural methods to minimise or eliminate the use of pesticides. If pesticides are used, a detailed record should be maintained and application methods minimising the quantities of chemicals required should be used (FSC 2020).

Methods for the Post-Harvest Treatment After Bush Thinning

The removal of bush creates a vacuum, which will be filled by other bushes that are sometimes more aggressive. This effect can be reduced by having a competitive grass layer and retaining large bushes that suppress re-growth. However, the higher the intensity of initial control, the higher the potential re-thickening. Land can only remain productive and in a desirable state by managing re-encroachment with a post-harvest treatment programme (Smit et al. 2015). A prerequisite of every post-harvest treatment programme should be responsible rangeland management (De Klerk 2004).

Controlled Fire

Overview

Fire is a part of savannas and responsible for the maintenance of the savanna ecosystems. It is a key ecological process regulating vegetation structure and species composition (Nepolo & Mapaure 2012). A fire regime includes the frequency, intensity and seasonality of fire (Lesoli et al. 2013).

Ground fires burn low on the ground and are spurred by debris and organic material. This type is rare and mostly restricted to forest ecosystems. The most common fires in grasslands are **surface fires** burning in the herbaceous layer. They can turn into **crown fires** by igniting the foliage of trees and shrubs. In addition, fires can be further subdivided into head fires (burning with the wind) or backfires (burning against the wind). **Head fires** reach higher temperatures above ground level and are more intense than backfires. They often release heat far above the ground by burning foliage. **Backfires** are hotter, but the heat is confined to the soil surface. Head fires are heavily influenced by the atmospheric conditions. (Dannhauser & Jordaan 2015).

Stem Burning: The use of a small, low intensity fire around the stems of woody species allows to selectively kill trees. The long application of heat can severely damage the bark and buds and can eventually kill the tree. It is not well suited for multi-stemmed species or trees with small stems (Smit n.d.).

Fire cannot always be applied. It depends on the ability of the ecosystem to support fire. A high intensity fire is required to control bush seedlings, coppice or maintain woody plants at a specific height for the use of browsers. Fire is better suited for areas with considerable rainfall and good soil moisture to support sufficient fuel load. The use of fires must be sustained with periodic follow-up burns (Lesoli et al. 2013). Different woody plants also have a different sensitivity to fire. While some species may be very sensitive to fire, others may be resistant or encouraged to germinate.

The use of fire is regulated by the Forest Act and Regulations and a Fire Management Strategy for Protected Areas has been developed.

Impacts

Fire can enhance the growth of herbaceous plants by removing inhibitors and replacing un-palatable species with palatable species (Nepolo & Mapaure 2012). It can have a considerable impact on seedlings, growth, survival and adult recruitment of woody plants (O'Connor et al. 2014). However, there is a risk of reducing basal cover to such an extent (after the area has already been thinned) that the bare ground is subject to soil erosion (Lesoli et al. 2013). A fire can also cause nutrient losses from the soil (Joubert et al. 2013). Too frequent burning can also have a negative impact on biodiversity.

Regrowth

Fire can kill most seedlings and ignite mature skeletons of bush, damaging and/or killing the regrowth. Some problem species regrow rapidly after fire and become more multi-stemmed (Joubert & Zimmermann 2017).

Mitigation & Recommendations

- Existing regulations (e.g. Forest Act, Draft Fire Hazard Areas Regulation) and guidelines (MEFT Fire Strategy for Protected Areas, etc.) on the use of fire must be followed to avoid fire getting out of control.
- Trampling animals before a controlled burn can prevent the soil from capping during a fire. Grazing livestock a few days before burning can also reduce the fuel load underneath large shade trees and minimise damage.
- The perennial grass seeds must have shed before burning.
- A fire should only be applied if enough residual soil moisture is available from the previous season to allow perennial grasses to grow in the absence of rain.
- The land should be rested for a year to allow grasses to regrow to suppress bush encroachment and accumulate enough fuel for a follow-up fire killing coppice and the rest of the seedlings (Joubert & Zimmermann 2017).

Biological Control

Overview
Biological control measures use living organisms to reduce the reproductive capacity, growth and effects of woody plants (Lesoli et al. 2013). Biological control can involve the introduction of grazers, browsers, invertebrates or diseases. The main aim of biocontrol is to ensure woody species can reproduce and grow but do not aggressively thicken (ibid).

1. **Wild Herbivores:** Browsers can either be used to control woody plants or use the forage produced by woody biomass in the long-term. The complete control or elimination of woody plants cannot be achieved through wildlife except for the elephant (Smit n.d.). Wild browsers and other seed predators can prevent woody species from establishing and proliferating. They can keep them at a state where they are vulnerable to fire, thereby supporting the maintenance of savanna systems. Maintaining native browsers can balance woody-grass vegetation, enhance biodiversity and create economic opportunities around consumptive and non-consumptive utilisation of game (Archer et al. 2017).
2. **Boer Goats** can successfully control bush encroachment because the intensity and frequency of their browsing can be managed. They are also insensitive to the high levels of chemical deterrents (e.g. tannin) in woody plants (Smit n.d.). Goats tend to avoid *Senegalia / Acacia mellifera* but can be used to control other species for example *Dichostachys cinerea* (Joubert et al. 2013).
3. **Invertebrates:** The seed-feeding weevil and other insects have been successfully used in South Africa to control alien *Acacia spp.* (Lesoli et al. 2013, Dannhauser & Jordaan 2015). Used together with plant-attacking biocontrol agents they completely kill the plants and should not be used if the wood is to be used for commercial purposes (Lesoli et al. 2013). Considerable research on the impact on other bush species, potential for host shifts and modes of application would be required for Namibia.
4. **Fungi:** Some Fungi species that caused considerable dieback in Namibian black thorn included *Phoma glomerate, Phoma eupyrena, Phoma cava* and *Cytosperma chrysosperma* (Van der Merwe 2007). Considerable research on the impact on other bush species, potential for host shifts and modes of application would be required for Namibia.
5. **Trampling:** Large herds of grazers can be used to trample and graze the area for a short period of time after which the land must be allowed to rest. Due to the trampling, more light is available for the herbaceous layer and urine and dung are deposited on site. It can give grasses a competitive advantage over woody plants who are less adapted to trampling (Van Oudtshoorn 2015).
6. **Wild Hares:** Some farmers believe that wild hares successfully control coppicing after initial bush thinning – especially if used together with goats (Stoldt & Perche 2020). Peter Cunningham noted that these are specifically *L. capensis* and *L. saxatilis* who feed on seedlings.
7. **Parasitic Plants:** Some parasitic plants spread by birds can infest large areas and cause dieback in woody plants (Stoldt & Perche 2020).

Impacts
Biocontrol agents can survive in a treated area for a long time. They are mobile, actively look for new target plants and re-establish themselves should tree density increase again. They can be a very inexpensive and environmentally sound measure if carefully screened (Lesoli et al. 2013, Van Oudtshoorn 2015). The use of goats can also contribute to higher meat production and income (De Klerk 2004). However, considerable research on how biocontrol agents could be employed is required to avoid hosts shifts for invertebrates and fungi and ensure they have the desired effect on target plants only. Native species should be used. Goats generally require considerable management to have a desired effect on regrowth (Smit n.d.).

Regrowth
If managed correctly, regrowth can be controlled – especially in conjunction with burning. In a Namibian trial, the combination of goats and fire reduced bush density by 60% within 40 years (O'Connor et al. 2014). A study by du Toit proved that intensive and frequent browsing by goats can reduce coppicing of *Vachellia / Acacia karroo* to 28% compared to areas where coppice was not controlled by goats (Smit n.d.).

Mitigation & Recommendations
The species that should be controlled must be part of the diet of goats and sufficient browse material must be available. If the controlled species is not preferred by browsers, invertebrates could be considered as biological control agents (Lesoli et al. 2013). The stocking rate of goats must be high enough to control re-growth (Van Oudtshoorn 2015). An annual stocking rate of 1 goat/ha appears to be too low to control *Senegalia/Vachellia* species but may be effective for *D. cinerea* at low densities (i.e. 500 plants/ha) (Zapke 1986). A stocking rate of 2 goats/ha stocked continuously or 10 goats/ha for a short duration in a rotational browsing system may be more applicable (van der Waal & Stoldt 2020).

Mechanical Control

Overview
The use of heavy machinery for post-harvest treatment purposes is rare but may be used after chemical control (e.g. with soil applied chemicals) when the trees remain standing.

Impacts
Mechanical control with heavy machinery can compact soils and cause considerable soil disturbance, which will impact the herbaceous layer. Grasses must completely re-establish themselves on the bare soil. The disturbance can also encourage the establishment of other problem plants (Smit n.d.).

Regrowth
The considerable disturbance can encourage the establishment of bushes (Smit n.d.) by preparing a seedbed with little initial herbaceous competition. When uprooting plants some roots can withstand, re-sprouting heavily and often changing their form from single- to multi-stemmed (Welch n.d.).

Mitigation & Recommendations
The use of heavy machinery for post-harvest treatment purposes should be discouraged, due to the high ecological risk and the limited benefits.

Manual Control

Overview
Manual methods for post-harvest treatment involves the digging out of roots as well as manually removing coppice or saplings e.g. with a mattock or Tree Popper (Joubert & Zimmermann 2017).

Impacts
Manual methods are very selective, minimise the impact on desired plants and provide considerable job opportunities for low skilled labour. Manually controlling regrowth can be very time consuming and may not be viable for larger areas. Digging up roots can have a negative impact on the soil structure.

Regrowth
If the root is not removed when taking out saplings, there will be regrowth (Joubert & Zimmermann 2017). Digging out the roots effectively controls regrowth and coppicing (Van Oudtshoorn 2015).

Chemical Control

Overview
Although soil-applied and plant-applied chemicals can be used for the post-harvest treatment of thinned land, for example for heavy re-sprouting after mechanical control or to control seedlings after fire (Lesoli et al. 2013), cut-stump application is the most viable option due to the costs of chemical control. **Cut Stump Application** normally takes place directly after mechanical control when the stumps are freshly cut (Van Oudtshoorn 2015). Foliar application to coppice or stems can also be used to control re-growth.

Impacts
If used correctly, cut-stump application can be very selective and have little off-site effects due to the low quantities used and the direct application to the plant – which considerably reduces the risk of chemical drift (of foliar application) and leaching (for soil-applied arboricides). It is however time consuming and relatively expensive (Joubert & Zimmermann 2017).

Regrowth
Cut-stump application prevents coppicing and, if effective, no further post-harvest treatment is required (Joubert & Zimmermann 2017). If not effective, there may be coppicing after chemical control.

Mitigation & Recommendations
Stems to be treated must be cut cleanly and cleaned of any residues or dust before applying the chemical. Follow-up treatments may be required to control coppicing. They are advised to be used in the active growing season, but good results may also be achieved throughout the rest of the year (Van Oudtshoorn 2015).

For foliar application, the use of adequate quantities and under the right conditions (no strong winds) is vital. Soil-applied chemicals should not be allowed for post-harvest treatment purposes, due to ecological risks.

Reseeding & Inter-Seeding

Overview

Effective bush management must include both top-down and bottom-up measures to ensure the maintenance of bush to a specific density and minimise the chances of re-growth and further densification. Seeding is used to give native or desired species a competitive edge (Woods et al. 2012). Sowing of perennial grasses can increase competition and reduce bush density more than thinning alone (O'Connor et al. 2014).

The seeds can be dispersed by livestock by mixing the seeds into their feed, which is the most cost effective, or by creating seedcakes, seed bombs or blocks by mixing the seeds with manure, biochar and other growth enhancers. They can also be dispersed with drones (Van der Waal & Stoldt 2020).

1. **Seeding:** Seeding practices involve the preparation of a seedbed before seeding or planting desired grasses (Phillips-Mao 2017).
2. **Inter-Seeding:** Inter-seeding into the remaining vegetation after bush thinning avoids soil disturbance. The seeds can be widely broadcast directly to the area following a fire. No seedbed preparation is required (Phillips-Mao 2017).

Impacts

Re-seeding local grasses can improve the competitive ability of the herbaceous layer, provide fodder for livestock and wildlife and enhance the accumulation of fuel for fires. Local seeds should be used to avoid potential changes to the ecosystem with unknown consequences. These seeds may not be commercially available and must be harvested on site, which is labour intensive and time consuming.

An adequate amount of water is required for seedlings to establish themselves. A lack of water and seedling establishment can have undesirable effects on the landscape e.g. by increasing soil erosion (Woods et al. 2012).

Regrowth

Seeding does not directly address the coppicing or regrowth ability of the thinned bush. It can only improve the competitive ability of grasses, which can suppress further bush growth. It must thus be combined with other post-harvest measures that control coppicing, seedling establishment and remove competition (Phillips-Mao 2017).

Mitigation & Recommendations

Inter-seeding should be used to minimise disturbance to the land. The use of seed bombs can protect the seeds from being carried away by insects or small mammals, while enhancing the establishment by adding manure or charcoal / biochar residues.

Inter-seeding is especially suited for selectively controlled areas with relatively fertile soils and some woody plants that provide shade and nutrients.

The specificities of the site should be considered when choosing seeds to avoid negative impacts on the remaining vegetation, wildlife and soil communities. Ideally, plants already present at the site should be used and locally harvested seed should be promoted. Species for reseeding could also be chosen based on historical records or reference sites (Phillips-Mao 2017).

The establishment of seeds can take a couple of years and will depend on factors such as soil moisture, climate and competitive pressure. Other post-harvest measures are vital to reduce competition and prevent re-thickening (Phillips-Mao 2017).

Soil Enhancement

Overview

The removal of biomass can have a negative impact on the soil – the severity depends on the initial bush control method used. To speed up the restoration of soil fertility, minerals removed through the harvesting of bush must be returned (Zimmermann et al. 2017), which can be achieved by using by-products of the initial thinning operation.

1. **Brush Packing** is the deposition of branches of cleared bush on thinned areas to promote seedling establishment and growth of grass. It can restore nutrients and moisture content in degraded soils (Mangani et al. 2018; Meyer 2020).
2. **Wood ash** is the residue from the burning of organic material and contains most of the trace elements and inorganic nutrients of biomass (Wiklund 2017). The ash from burning woody biomass is widely used as agricultural soil amendment. It can raise the pH of the soil and add nutrients (Saunders 2014).
3. **Wood acid** is a side-product of charcoal production when the smoke is distilled and left to stand for 3 months to naturally purify. It is used for various purposes including as animal feed supplement, odour remover, insect repellent as well as foliar and soil fertiliser (Mungkunkamchao et al. 2013). Wood acid consists of various acids, compounds and minerals (Sadakichi & Hirowaka n.d.).
4. **Charcoal / Biochar** is very porous and thus easily retains moisture. It can improve the soil by increasing water retention and water permeability. It can also increase useful microbes, which encourages stronger root development, and can protect plants against insects. Due to the carbonisation process, it also has some minerals including boron and calcium that can be easily absorbed by plants (Sadakichi & Hirowaka n.d.).

Impacts

Brush packing is a cost-effective measure requiring no additional inputs (Sebitloane et al. n.d.). It can create a micro-habitat favourable for the recruitment and growth of grasses and protects new seedlings from herbivory (Kellner 2019). It can decrease soil surface temperatures and improve the soil moisture content of the soil layer due to the shade effect of the woody branches (Meyer 2020). In addition, it can reduce runoff and increase infiltration rates (Van Oudtshoorn 2015; Mangani et al. 2018; Meyer 2020). As the woody branches decompose over time, it can increase the nutrient and carbon content of the degraded soils (NWU, n.d.).

Wood ash, charcoal and biochar can also replenish important soil nutrients and improve the porosity of the soil, which has positive impacts on water retention (Sadakichi & Hirowaka n.d.; Lehmann et al 2011).

Regrowth

Soil enhancement measures do not directly address the regrowth and coppicing ability of plants. However, they address one of the key causes of bush thickening: A low soil fertility, which shifts the competitive balance towards bushes.

Mitigation & Recommendations

Brush Packing: The brush (woody branches/twigs) used should be placed against the flow of water to trap any other organic material and if possible, to a height not exceeding 1.5m. Branches should not be stacked on top of each other but spread evenly over the area for total coverage (Mangani et al. 2018). This should be done right before the rainy season (Stoldt & Perche 2020).

Grazing Management

Overview

After bush control efforts, the treated area must rest to ensure the recovery of the herbaceous layer. A sustainable grazing or veld management programme should be developed to control re-growth (Dannhauser & Jordaan 2015).

1. **Kraaling** cattle overnight on the piece of land to ensure deposition of their dung and urine but grazing them elsewhere is advised. It means that less nutrients are deposed in the grazing areas, so there is a trade-off between bush-thinned land and current grazing sites (Zimmermann et al. 2017).
2. **Rotational Grazing:** Moving cattle to different portions of the pasture (paddocks) while the other portions rest. The intent is to allow plants and soil time to recover (Undersander et al. 2002). The NRMP best practices document details different options e.g. Split Ranch Approach, Holistic Grazing with different recovery periods, the use of 8 Camps, Mara Fodder Bank Grazing Management and Ultra-High Density Grazing (Nott et al. 2019).
3. **Supplements:** Livestock can be supplemented with biochar and mineral rich ocean products, such as kelp, which are excreted and transferred into the soil by dung beetles (Zimmermann et al. 2017). There are also supplements to encourage livestock to browse more (Stoldt & Perche 2020).

Impacts

Responsible grazing management can lead to more stable production during droughts, greater cattle yield potential, a higher quality grass, less weed and erosion problems (Undersander et al 2002), promote uniform soil fertility levels and potentially limit conflict with wildlife. It does however require considerable management and expertise.

Regrowth

Sustainable grazing management measures alone in heavily degraded areas might not be sufficient to control regrowth and must be combined with other restorative measures (Stoldt & Perche 2020).

Mitigation & Recommendations

Responsible grazing management should be a key component in every bush thinning programme.

Sustainable grazing management measures should be widely adopted in bush thickened areas to limit risks of overgrazing and land degradation. Specific measures following bush control interventions should be implemented based on grass recovery.

Pruning

Overview

After the initial thinning of areas with thick bush, the regrowth of the bush often has a different structure and species composition compared to the original stands (Smit et al. 2015, Cunningham & Detering 2017). Harvested single stem trees coppice after harvesting and become multi-stemmed trees. These trees require pruning like plantation forestry (Cunningham & Detering 2017).

Pruning removes the branches of bushes or trees instead of harvesting the entire plant. It encourages the bush to grow outwards and prevents heavy re-sprouting. Only the useful branches of trees and bushes are removed, and smaller branches are left for future harvesting (Baldiga et al. 2008). The main tools are shears for smaller branches or saws for larger branches (Hodel & Pittenger 2002).

Pruning must be further trialled and tested in the Namibian context. Pruning coppiced bush too soon (e.g. within a season) or too drastically after the initial harvest resulted in a high mortality rate of the pruned plants in Namibian studies (Van der Waal & Stoldt 2020).

Impacts

Pruning can help to shape young plants into desired forms (Hodel & Pittenger 2002) to ensure they can be used for different value chains. Pruning and thinning can ensure that patches of woody plants are maintained contributing to habitat heterogeneity and species diversity (Joubert & Zimmermann 2002).

Done incorrectly, pruning can do considerable damage to the shape and structure of the plant. Pruning trees when they become larger can be harder and less effective due to scarring and excessive regrowth (Hodel & Pittenger 2002).

Regrowth

The bush continues to grow as the main objective is to maintain the plant and consistently harvest larger branches leaving the smaller branches for future harvesting.

Mitigation & Recommendations

Pruning should go hand in hand with soil enhancement measures to ensure the sustainability of the resource base. Further measures to ensure densities are appropriate to produce good quality woody biomass and easy access to the resources for harvesting.

To maintain growth, pruning should be done in spring, which is often the season of most rapid plant growth. Shaping young trees is also best done in the growing season. To slow plant growth, plants should be pruned towards the end of their growing for the season (Hodel & Pittenger 2002).

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