THE ECONOMICS OF LAND DEGRADATION

Economics of Land Degradation Initiative: **Benefits of bush control in Namibia**

A national economic study for Namibia and a case for the Otjozondjupa Region

www.eld-initiative.org

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About the Support to De-bushing Project

Acknowledging the overall importance of bush control, the governments of Namibia and Germany agreed on a 4-year bilateral project to address both the challenges and opportunities that bush encroachment entails. Launched in 2014, the Support to De-bushing Project is jointly implemented by the Namibian Ministry of Agriculture, Water and Forestry (MAWF) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

The project's overall objective is to develop strategies for upscaling sustainable bush control activities to reduce bush encroachment in Namibia, supported by both public and private sector stakeholders. The project has three key approaches:

- to improve the legal and institutional frameworks for large-scale bush thinning projects,
- to enhance know-how and institutional capacities for the successful development of a national bush thinning programme, and
- to identify and develop value addition opportunities for the profitable use of biomass.

The Project is testing three value chains during the course of its project lifetime, namely the value chains of charcoal, animal feed and biomass energy.

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Executive Summary

Bush encroachment is increasing

Bush encroachment has increased significantly in Namibia and the scale is alarming. It is estimated that more than 30 million hectares (30 per cent) of farmland are affected by bush thickening.

The environmental impact is serious and agricultural production continues to decline. Bush encroachment potentially affects multiple ecosystems and land uses in Namibia, both in communal and commercial areas.

Bush encroachment has negative impacts on some of Namibia's key ecosystem services, such as livestock production, groundwater recharge and tourism, as well as biodiversity. While the concerns about agricultural productivity are well recognised, the impacts on other ecosystem services are less considered but just as important.

Bush control generates benefits

The term "bush control" refers to the active management of bush densities and thus constitutes a counter-measure to bush encroachment. Bush control involves preventative measures (e.g. sustainable rangeland management), active rehabilitation measures (e.g. bush thinning through harvesting of a defined number of bushes per hectare) and follow-up measures (i.e. aftercare).

Bush thinning can be done by manual, mechanised or chemical means. Each control method has different challenges and opportunities and should be selected based on factors such as soil and vegetation type, location, or land use.

Bush control could generate benefits including for livestock production, tourism, groundwater recharge, biodiversity and employment. It offers economic opportunities for the utilisation and/or local value addition of woody biomass via charcoal and firewood production, electricity generation, and other means.

Apart from these benefits, bush control is also likely to have some negative effects and environmental costs. Mechanical means of bush harvesting can disrupt the soil and non-encroacher vegetation while chemical means have the potential to poison non-target vegetation, fauna and water sources. As bushes are a carbon sink, bush thinning will decrease the amount of carbon sequestered in the soil as well as in the woody component. Furthermore, if cattle stocks increase in response to bush control, this would increase greenhouse gas emissions.

Benefits are higher than direct costs

In this study, many key ecosystem services are valued. These values are fed into a cost-benefit model. Thereby, the net benefits of bush control, compared with a scenario of no bush control, are estimated. The study follows the methodology developed by the Economics of Land Degradation (ELD) Initiative.

Two cases are discussed: a national Namibia case and a case concentrating on the Otjozondjupa region in central Namibia. The national study calculates costs and benefits that could arise following a bush control programme; the Otjozondjupa study additionally factors in investments needed to unleash the benefits for ecosystem services. On both national and regional level, the value of the ecosystem services is higher than the direct costs involved. As some unquantified ecosystem services would be positively affected by bush control, it is reasonable to expect that there is upside risk to the following estimates:

In the national study, the total potential benefits from ecosystem services are estimated at N$ 76.2 billion (USD 6 billion)[1] (2015 prices, discounted) over 25 years, while the total costs of a bush control programme are estimated at N$ 28.1 billion (USD 2.2 billion). This results in estimated potential net benefits of N$ 48 billion (USD 3.8 billion) at national level.

1 *Values rounded to one decimal place. 1 USD = N$ 12. 6966 (01 August 2015).*

In the Otjozondjupa study, the total benefits are estimated at N$ 25.1 billion (USD 2.0 billion) (2015 prices, discounted) over 25 years, while the total costs are estimated at N$ 20.3 billion (USD 1.6 billion). This results in estimated net benefits of N$ 4.9 billion (USD 0.4 billion) at regional level.

The Otjozondjupa study confirms the overall positive results of the national study. Additionally, the regional study finds that 50 per cent of net benefits are required as investments to unleash benefits.

Bush control can make a considerable contribution to Namibia's welfare

The national study does not take into account the investments required to unlock the potential benefits of bush control (e.g. purchase of additional livestock to utilise extra carrying capacity). However, if the investment required to unlock potential ecosystem service benefits is less than N$ 48.0 billion (USD 3.8 billion), bush control would generate a positive Net Present Value (NPV). The Otjozondjupa study estimates the net benefit for additional cattle production to amount N$ 146 million (USD 11.5 million) in the region alone.

Ultimately, the data clearly show that bush control and biomass utilisation can make a considerable contribution to Namibia's welfare and economic growth.

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Acronyms

BAU	Business as usual
BMZ	German Federal Ministry for Development and Economic Cooperation
CICES	Common international classification of ecosystem services
ELD	Economics of Land Degradation Initiative
FAO	UN Food and Agriculture Organisation
GIZ	Gesellschaft für Internationale Zusammenarbeit
HFO	Heavy fuel oil
HIV/AIDS	Human immune deficiency virus/Aquired immune deficiency syndrome
INPs	Indigenous natural plant products
IUCN	International Union for Conservation of Nature
LDN	Land degradation neutrality
MLR	Ministry of Land Reform
MPC	marginal propensity to consume
MPI	marginal propensity to import
MTR	marginal tax rate
MW	megawatt
NamWater	Namibia Water Corporation
NamPower	Namibia Power Corporation
NPV	Net present value
MAWF	Ministry of Agriculture, Water, and Forestry
MITSMED	Ministry of Industrialisation, Trade and SME Development
ResMob	Resource Mobilisation Project
SAIEA	Southern African Institute for Environmental Assessment
SOC	Soil organic carbon
SCC	Social cost of carbon
TEV	Total economic valuation
UNDP	United Nations Development Programme

Introduction

Bush encroachment in Namibia

Bush encroachment is defined as the invasion and/or thickening of aggressive undesired woody species, resulting in an imbalance of the grass to bush ratio, a decrease in biodiversity, and a decrease in carrying capacity[2] (De Klerk, 2004). It is estimated that more than 30 million hectares (30 per cent) of farmland are affected by bush thickening. The phenomenon has resulted in significant negative environmental impacts, such as the reduction of ground water recharge, loss of habitat (e.g. for cheetahs), species loss (endemic plants, reptiles and birds) as well as a lower grazing potential of farmlands, leading to an overall decline in agricultural production. A correlation between heavy grazing pressure, cattle farming and bush encroachment seems evident. Encroachment is much higher on the freehold farms than in any other farming systems (Mendelsohn, 2006).

Study context

Since 2014 the governments of Namibia and Germany carry out a bilateral cooperation to address both the challenges and opportunities that bush encroachment and according control programs entail for Namibia. The Support to De-bushing Project is jointly implemented by the Namibian Ministry of Agriculture, Water and Forestry (MAWF) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (on behalf of the German Federal Ministry for Development and Economic Cooperation (BMZ)). Their joint goal is to trigger large-scale bush thinning activities. Under this umbrella and in order to develop value addition opportunities for the profitable use of biomass, the Namibia Nature Foundation was commissioned with two studies by the ELD Initiative as well as the Support to De-bushing project. The studies intend to shed light on the various economic dimensions of the phenomenon of bush encroachment and to support economically deliberate and environmentally sustainable decisions on land and biomass use options.

Purpose of this report

This report provides a synthesis of the two studies on the economics of land degradation in relation to bush encroachment, conducted at national (Namibia) and regional level (Otjozondjupa Region). The Total Economic Valuation (TEV) framework used in the national assessment values the potential costs and benefits of a bush control programme for ecosystem services as well as the direct costs of bush control operations. The Otjozondjupa case builds on the framework developed in the national assessment and factors in additional use option. Moreover, it estimates the financial costs involved in unlocking the ecosystem service benefits and some of the wider economic impacts to build a business case for bush thinning. The delineation of bush encroachment in the Otjozondjupa case is based on data collected by the Namibian Land Degradation Neutrality (LDN) pilot project in 2016.

The key objectives of the national study are:

- to provide initial economic valuations of costs and benefits of bush control, and
- to provide a framework that can be used to guide policy development and processes.

The objectives of the regional study are:

- to establish a regional assessment of economic opportunities with a specific focus on additional benefits from spin-off effects, and
- to build on work undertaken for the Otjozondjupa LDN pilot project and to complement the Integrated Land-use Plan.

The analyses provide useful information for decision makers on approaches to a bush thinning programme and can be used to decide on appropriate support measures, such as incentive schemes.

2 *The number of animals that can be kept sustainably in areas of natural vegetation for optimal production and without overgrazing, i.e. the number of hectares required for each large or small stock unit.*

CHAPTER

02

Methodology

Both studies follow the methodology of the Economics of Land Degradation (ELD) Initiative with a Total Economic Valuation framework (ELD, 2015). Relevant key ecosystem services are valued and these values are fed into cost-benefit models to estimate the net benefits of bush control when compared with a business-as-usual (BAU) scenario of no bush control.

Some changes to the 6+1 step ELD approach have been made in response to data availability and other environmental economic approaches in Namibia. These variations from the general ELD approach should not impact the validity of the final product.

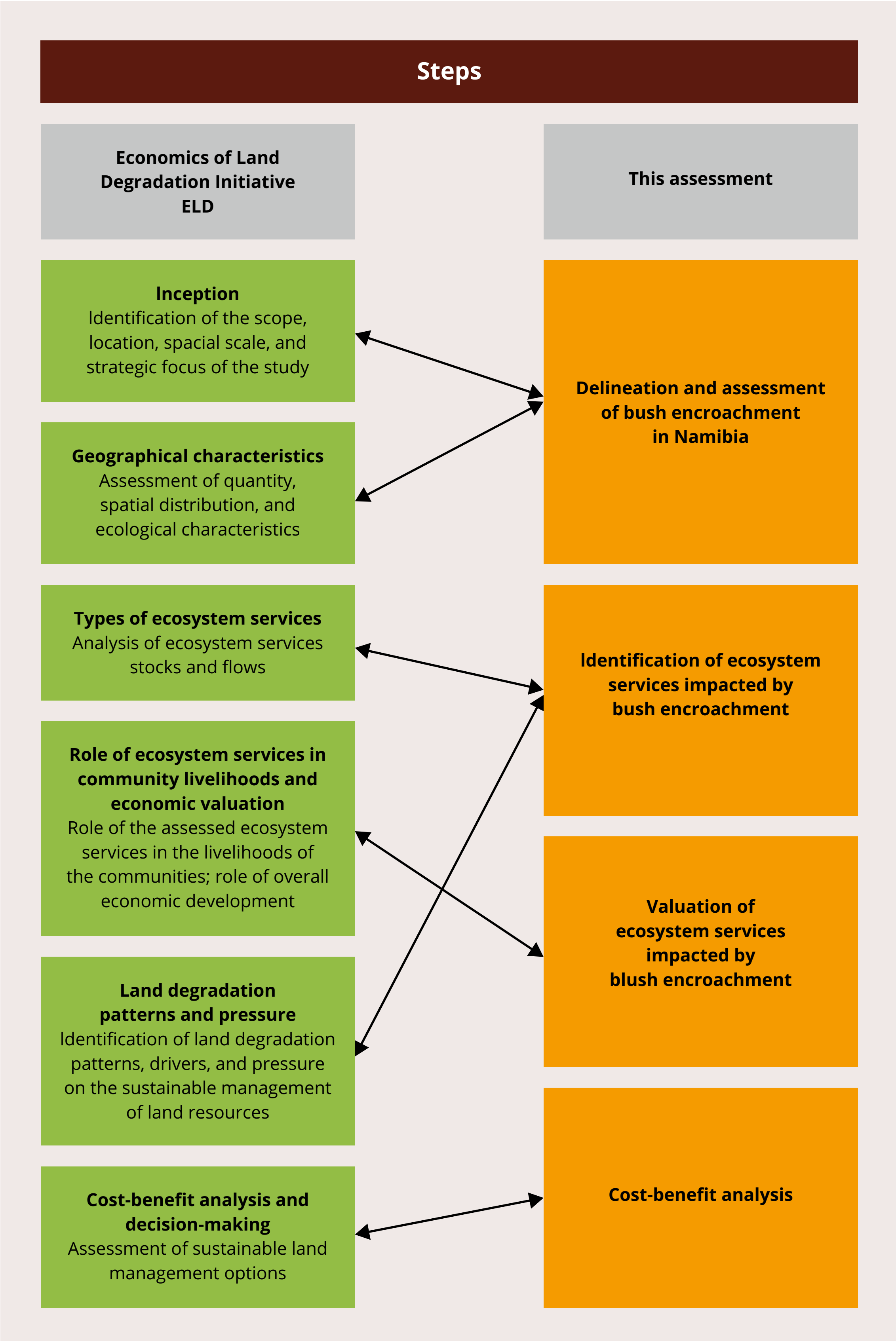
To identify the ecosystem services affected, this report adopts the Common International Classification of Ecosystem Services (CICES). One of the key limitations of the studies is the deficiency of data and knowledge on how ecosystem services are affected by bush encroachment and bush control – groundwater recharge rates, for example. Given these data and research constraints, the likely impacts of bush control on the majority of services could not be quantified. Furthermore, data on ecosystem service values, particularly in the Namibian context, is lacking. However, there is reason to believe that many of these services would be positively affected by bush control, which suggests that there is upside risk to the estimates of benefits.

By using a Total Economic Valuation framework, the national study only values the costs and benefits for ecosystem services from bush control against the direct cost of bush control operations. It does not quantify the investment that would be necessary to unlock the potential ecosystem service benefits. In the Otjozondjupa case, however, financial costs of increased livestock production are estimated (on an aggregate level).

Investment costs vary significantly by sector. For livestock production, they would include the purchase of additional livestock, feed, fences, and labour to manage the stock; for tourism, accommodation, vehicles, or the purchase of wildlife stock; for value added industries, such as charcoal production and electricity generation, investments in plants and buildings, machinery, equipment, and labour. These costs would be significant in determining which industry offers the greatest return for their "biomass" product or service.

FIGURE 1

Methodology of the ELD Initiative and the underlying studies



03 Delineation and assessment of bush encroachment in Namibia

Namibian ecosystems affected by bush encroachment

Bush encroachment affects multiple ecosystems in Namibia. The presence and influence of bush encroachment was analysed based on an inventory of ecosystem services by the Namibia Nature Foundation (Harper-Simmonds et al., 2015):

- Highland Acacia Savannah: moderate encroachment densities of around 3,000–4,000 bushes per hectare
- Etosha Pans and Shrublands: moderate encroachment densities of around 3,000–4,000 bushes per hectare
- Karstveld: moderate densities of 3,000–4,000 bushes per hectare in the west and very high densities of 10,000 bushes per hectare in the east
- Western Highlands: impact not as severe, average densities at around 3,000 bushes per hectare
- Dry Kalahari Woodlands: moderate to high encroachment densities of around 3,000–8,000 bushes per hectare in the northern half
- Northern Kalahari Woodlands: high encroachment densities of around 5,000–10,000 bushes per hectare in its western half
- Nama Karoo Shrublands: low encroachment densities in an area focussed around Mariental of approximately 2,000 bushes per hectare
- Cuvelai Drainage: moderate encroachment densities of around 4,000 bushes per hectare in its southern part

FIGURE 2

Bush encroachment and ecosystems in Namibia

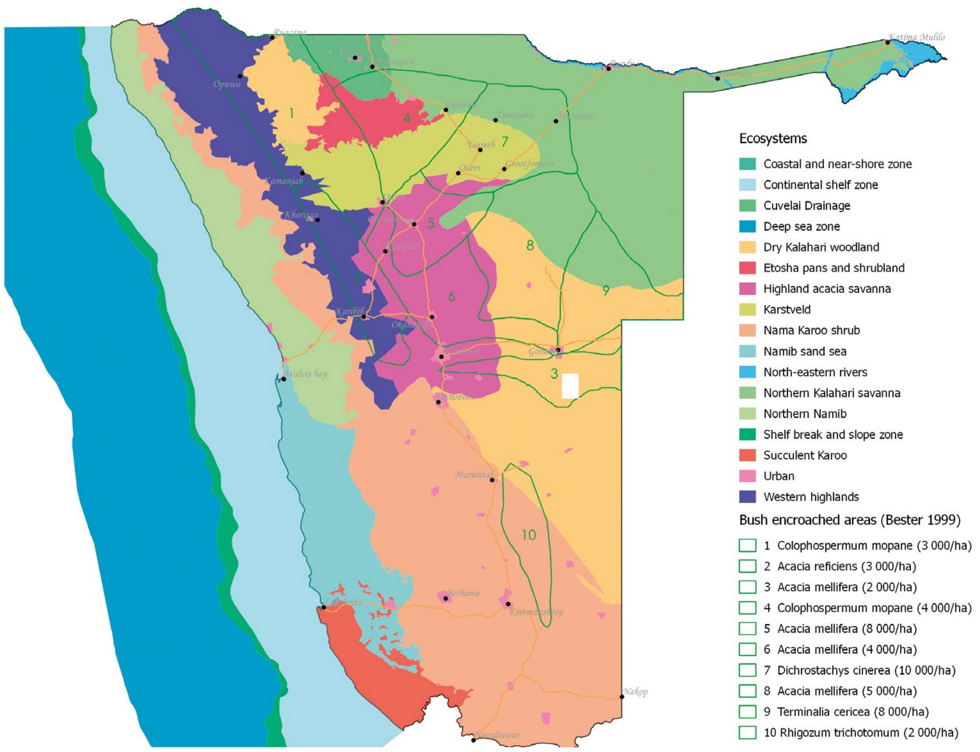
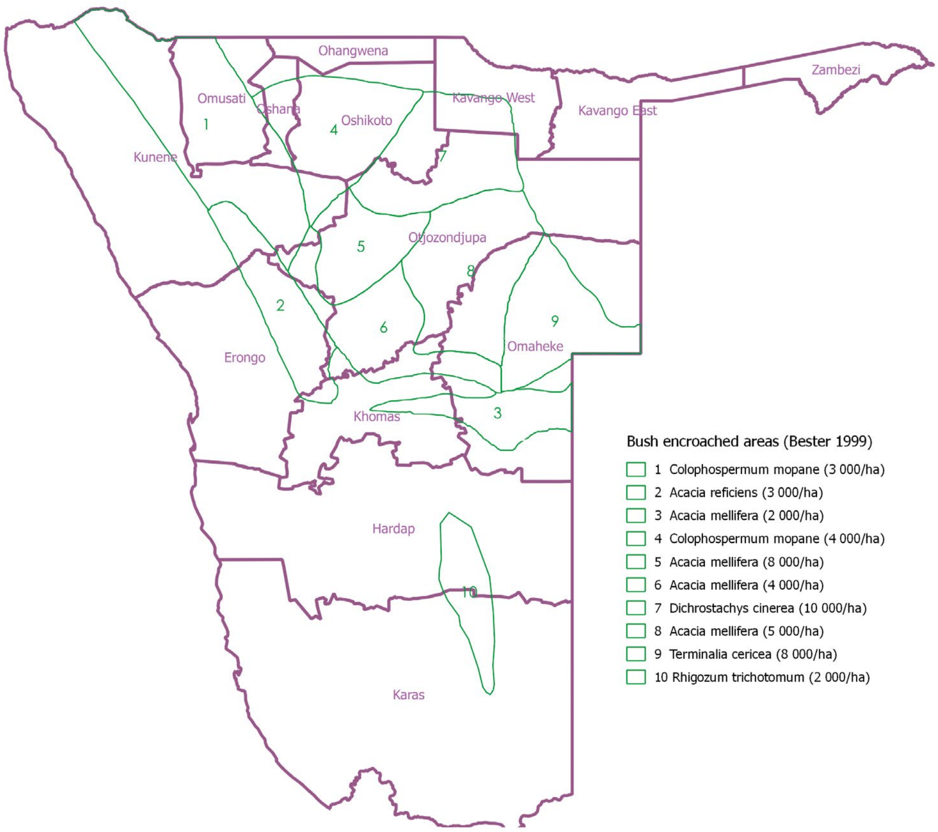


FIGURE 3

Range and density of bush encroachment across political regions of Namibia



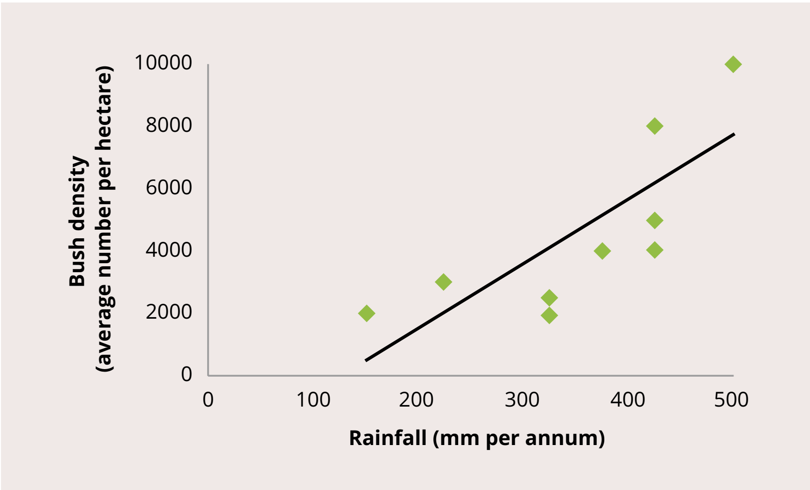
The bush-thickened areas fall mainly into the semi-arid savannahs with rainfall varying from about 300 mm in the west to about 500 mm in the northeastern parts (Joubert and Zimmermann, 2002). Bush encroachment affects nine of the fourteen political regions in Namibia, but the densest encroacher bush can be found in Otjozondjupa, Oshikoto, Kavango West, and northern Omaheke. Bush encroachment tends to be less in the drier regions, such as Hardap, Karas, Kunene, Erongo, Khomas and southern Omaheke.

As would be expected, bush density tends to be higher in areas of greater average rainfall. Higher volumes of water support greater numbers and growth, particularly when grasses have been compromised by overgrazing and drought. In the southern and western regions of the country, bush encroachment does not appear to be a significant problem, but moving northeast (in the direction of increasing rainfall), bush densities tend to increase.

The positive correlation between rainfall and bush density is illustrated in the chart below.

CHART 1

Rainfall and bush density



Drivers of bush encroachment

Overgrazing is found to be one of the key drivers of bush encroachment. It causes a decrease in the root base of grasses, reducing their competitiveness with regard to water and nutrient uptake and weakening their suppressive effect over emerging bushes. Favourable conditions for woody plants are created, especially when periods of drought, which reduce the grassy layer, are followed by periods of high rainfall.

However, the relationship is complex and, depending on the area and nature of encroachment, other factors include:

- the displacement of browsers, such as kudu by cattle or other grazing livestock, which puts extra pressure on the grassy component and relieves pressure on the woody plants, which flourish;
- increased CO_2 concentrations in the atmosphere may also encourage the growth of woody species over grasses;
- changing climatic conditions, i.e. higher rainfall, is associated with higher densities of bush;
- the suppression of high-intensity fires, due to cattle farming, which would otherwise kill the seedlings and saplings of woody species.

Impacts of bush encroachment

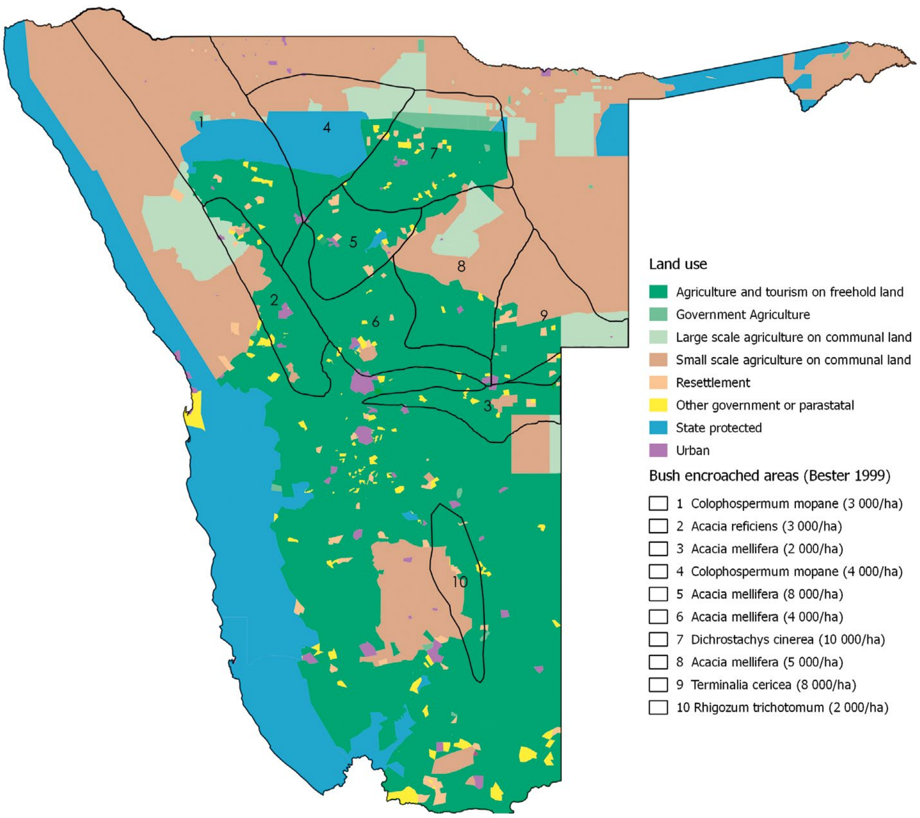
Impacts vary depending on the environment (e.g. types of soil, other vegetation, wildlife), how the land is used (e.g. cattle farming, tourism), and how many people depend on the land. Services of significant value to Namibia, such as grazing areas for livestock production, groundwater recharge, tourism and biodiversity, are negatively affected.

Livestock farming

Overgrazing, particularly by cattle, is a key contributor to bush encroachment, so it comes as no surprise that bush encroachment is concentrated

FIGURE 4

Bush encroachment and land use in Namibia



Cattle farming in central parts of Namibia

in areas of livestock farming. Bush encroachment has reduced carrying capacities by at least half (estimated average). This also compromises food security and nutrition, particularly in communal areas.

Game farming

Bush encroachment's net impact on game farming is less understood. On the downside, it may reduce land for wildlife, but there could be a positive effect if some farmers replace cattle and other domesticated animals with game. It is therefore difficult to assess whether bush encroachment results in a net gain or loss of outputs such as game meat and skins. Furthermore, browsers (e.g. goats, kudu, eland, dik-dik, black rhino and gemsbok in dry seasons) can actually benefit from a certain degree of bush encroachment, which expands their food source.

Tourism

Tourism operators have also been affected, as dense bush can undermine wildlife viewing, hunting, other activities such as hiking, and landscape appreciation. Dense bush reduces the opportunity and success rates for viewing or hunting, decreases the diversity of species, and reduces the enjoyment that individuals gain from viewing wide, open landscapes which are symbolic of Namibia. This may result in fewer visitors, lower satisfaction levels, and less revenue. However, the relationship between bush encroachment and tourism activities is quite tenuous, and it is difficult to isolate the net impact of bush control on these services.

Biodiversity

Biodiversity is not explicitly categorised as an ecosystem service, but it has a strong correlation with many ecosystem services. Diversity in animals, plants, and soil organisms can improve water and soil quality, increase the yield of several services (such as crop production), reduce yield variance, and improve resilience of ecosystems and their services. It can boost tourism and other cultural services and improve regulation and maintenance services. As such, many of the values of biodiversity are captured in the values of ecosystem services. Bush encroachment is believed to have a negative impact on biodiversity, as the rangelands deviate from the optimal mix of vegetation and alter the natural balance of wildlife. Bush control, up to a point, is therefore believed to have a positive impact on biodiversity, if managed correctly.

Groundwater recharge

Bush encroachment increases the rate of evapotranspiration, reducing groundwater recharge rates compared with grassland. Bushes intercept some rainwater before it reaches the ground, which then evaporates into the atmosphere. They also compete with grasses to take up significant amounts of water from the soil through their root systems. During transpiration, which is the process of water being carried from roots to leaves and evaporating, the main loss of water occurs.

Impacts of bush encroachment on ecosystem services

The following tables reflect the relevance of selected ecosystem service to bush encroachment and the likely direction of change in the service due to bush control. For many ecosystem services, there is little data or research on how they might be impacted by bush control. A more detailed discussion on the expected changes of a broader range of ecosystem services and how these may be valued can be found in the full national study report of the Namibia Nature Foundation (Birch, C., Harper-Simmonds, L., Lindeque, P. and Middleton, A., 2016).

TABLE 1

Provisioning ecosystem services* – impacts of bush control

Relevance	Ecosystem service class	Example	Estimated direction of impact from bush control
High	Reared animals and their outputs	Beef production	+
High	Groundwater for drinking and non-drinking uses	Drinking water, non-drinking water	+
High	Plant-based resources	Charcoal and firewood production, electricity generation	+
Medium	Cultivated crops	Maize, vegetables, sorghum etc.	+
Medium	Wild plants, algae and their outputs	INPs (e.g. Devil's Claw)	+
High	Wild animals and their outputs	Game meat, skins	+/−
Medium	Surface water for drinking and non-drinking uses	Drinking water, non-drinking water (e.g. domestic use)	+/−
High	Fibres and other materials for direct use or processing	Materials for construction	+
High	Materials for agricultural use	Animal feed supplement	+/−

** Provisioning services are understood to be all nutritional, material and energetic outputs from living systems (Haines-Young and Potschin, 2013).*

TABLE 2

Regulation and maintenance ecosystem services* – impacts of bush control

Relevance	Ecosystem service class	Example	Estimated direction of impact from bush control
High	Global climate regulation by reduction of greenhouse gas concentrations	Carbon sequestration	−
Unknown	Bio-remediation by micro-organisms, algae, plants and animals	Detoxification, decomposition and mineralisation.	Unknown
Unknown	Filtration / sequestration / storage / accumulation by micro-organisms, algae, plants and animals	Filtration and sequestration of pollutants in soil.	Unknown
Unknown	Filtration / sequestration / storage / accumulation by ecosystems	Filtration / sequestration / accumulation by ecosystems	Unknown
Unknown	Dilution by atmosphere, freshwater and marine ecosystems	Dilution by atmosphere / freshwater systems	Unknown
Low/none	Mediation of smell/noise/visual impacts	Screening of transport corridors	−
High	Mass stabilisation and control of erosion rates	Control of soil erosion	+
High	Buffering and attenuation of mass flows	Buffering of mass flows	+
High	Hydrological cycle and water flow maintenance	Groundwater recharge	+
Low/none	Flood protection	Flood protection along rivers	−
Medium	Ventilation and transpiration	Ventilation and transpiration	−
Low/none	Pollination and seed dispersal	Pollination	+/−
High	Maintaining nursery populations and habitats	Habitats for species	+/−
Unknown	Pest control	Pest control	Unknown
Unknown	Disease control	Disease control	Unknown
High	Weathering processes	Restoration of soils	+
High	Decomposition and fixing processes	Nitrogen fixing and nutrient replenishment	+/−
Medium	Chemical condition of freshwaters	Condition of water in rivers and dams	+/−
Unknown	Micro and regional climate regulation	Local climate, air quality, regional precipitation	Unknown

* *Regulation and maintenance services cover all the ways in which living organisms can mediate or moderate the ambient environment that affects human well-being (Haines-Young and Potschin, 2013).*

TABLE 3

Cultural ecosystem services* – impacts of bush control

Relevance	Ecosystem service class	Example	Estimated direction of impact from bush control
High	Experiential use of plants, animals & landscapes	Wildlife viewing	⊕
High	Physical use	Trophy hunting	⊕
Medium	Scientific	Scientific research	⊕/⊖
Medium	Educational	Education	⊕/⊖
Medium	Heritage, Cultural	Ways of life	⊕/⊖
Low/none	Entertainment	Ex-situ viewing of wildlife / landscapes	⊕
Medium	Aesthetic	Aesthetic appreciation of landscape	⊕
Medium	Symbolic	Symbolic identification of landscape features	⊕
Unknown	Sacred and/or religious	Scared practices of communities	Unknown
Medium	Existence	Existence value to current generations	⊕
Medium	Bequest	Bequest value to future generations	⊕

* *Cultural services cover all the non-material, and normally non-consumptive, outputs of ecosystems that affect physical and mental states of people (Haines-Young and Potschin, 2013).*

National Study

The assessment on national level values the potential costs and benefits of a bush control programme for ecosystem services as well as the direct costs of bush control operations.

Key assumptions

Some key assumptions and estimates underpin the valuation of ecosystem services under a scenario of the implementation of a national bush thinning programme:

- 60% of the identified bush-encroached land are to be thinned (15.8 million hectares).
- Encroacher bush density is to be reduced by 67% (two-thirds) in the central case and 33% (one-third) in a key alternate scenario.
- 5% of the targeted bush-encroached land is to be thinned per year. This would be equivalent to 787,770 hectares per year.
- A time horizon of 25 years was selected. This time frame captures the 20 years spent on the initial bush control and allows time for ecosystem services, such as livestock production and groundwater recharge, to reach their new potential.
- Real prices in Namibian dollar (base year 2015[3]) were used.
- A real discount rate of 6% per annum was applied in the central case based on the real discount rate used in the Wildlife Resource Accounts of Namibia of 2004.

Volume of harvested biomass

Zimmerman and Joubert (2002) estimate that across the ten bush encroached zones in Namibia, 134.9 million tonnes of harvested bush could be utilised for charcoal production. Wood suitable for charcoal production should be between 20mm and 150mm in diameter (Zimmerman and Joubert, 2002). Wood of this size is also suitable for firewood and electricity production, the other key uses of

Encroacher wood

[3] *1 USD = N$ 12. 6966 (01 August 2015)*

biomass discussed in this report. Consequently, this study assumes the potential harvested volume to amount 134.9 million tonnes, if encroacher species were 100% cleared across the entire bush-encroached area. Applying the key assumptions, this gives an estimate of 54.0 million tonnes of biomass that could be thinned initially. It is assumed that 5% of this total volume, or 2.7 million tonnes, could be thinned per year. A waste factor of 10% is assumed between harvest and use.

Valuation of key ecosystem services impacted by bush encroachment

Grazing land for livestock

The national study focused on grazing land for beef production because it is the dominant livestock production system in the bush-encroached zones. Firstly, an estimate of the changes in livestock numbers was accounted for and secondly, an estimate of the monetary value of this change.

Estimating additional cattle from increased carrying capacity due to bush control

- Based on farmers' experience, this study follows the assumption that a reduction in bush density to 33% of current density would at least double carrying capacity.
- It was assumed that it would take four years for carrying capacity to double in the bush controlled area.

→ In a scenario of bush control, carrying capacity for the entire bush-encroached area of Namibia would have doubled by the end of Year 23. It is implicitly assumed that the current carrying capacity is being fully utilised.

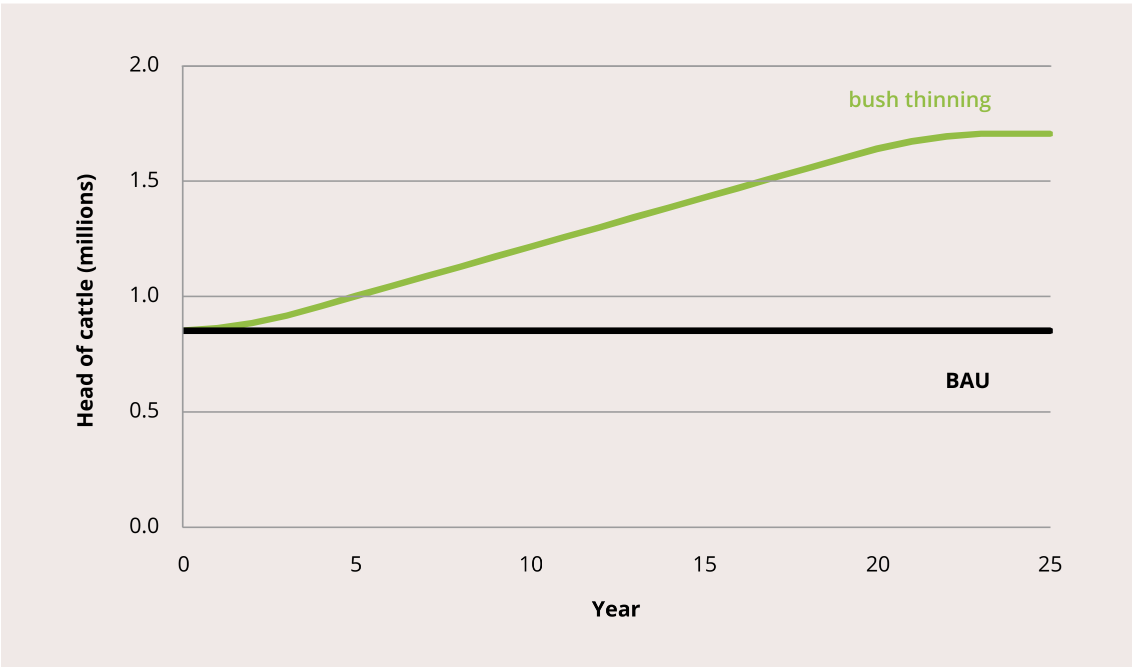
Valuing the increase in cattle

- The average producer price for beef in 2015 of N$ 27.3/kg (USD 2.2/kg)[4] was applied.
- A 'business as usual' scenario for no bush control was also set up under which cattle numbers remained constant.

→ The difference between the revenue in each of these two scenarios represents the benefit that would be gained from increased beef production due to bush control. This potential benefit was estimated at **N$ 6.4 billion (USD 0.5 billion)** over the 25 year horizon.

CHART 2

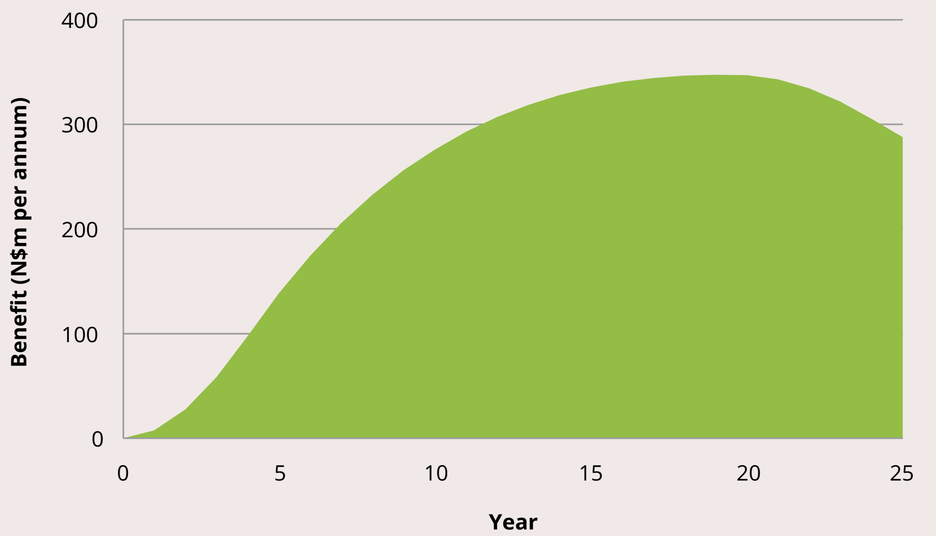
Head of cattle – bush control scenario versus BAU scenario



[4] *Meat Board of Namibia, latest available data (period of August 2015)*

CHART 3

Potential benefit of increased beef production



Sensitivity analysis

Key variables, namely the change in carrying capacity and the price, were varied in order to observe their impacts on the estimated benefit. It was found that the estimated potential benefits ranged from a low of N$ 3.2 billion (USD 0.3 billion), when carrying capacity only increased by 50%, and a high of N$ 12.7 billion (USD 1.0 billion), when carrying capacity tripled. Changes in prices had a lesser impact, with estimated benefits ranging from N$ 5.1 billion (USD 0.4 billion), when the price was 20% lower, to N$ 7.6 billion (USD 0.6 billion), when the price was 20% higher.

Limitations and risks

- The relationship between carrying capacity and bush density was estimated using a rule of thumb, rather than robust data.
- The forecasts of cattle numbers do not allow for influences such as weather patterns, social trends, and competing industries.
- Increasing stocking rates may result in overgrazing if good rangeland management is not practiced, encouraging bush encroachment again and perpetuating the cycle.
- The price is held constant in real terms, which is unrealistic. There will be price fluctuations, which may put upward or downward pressure on stock and offtake rates.

Groundwater

The cost/benefit of the change in groundwater flows due to bush control (compared with no bush control) was undertaken through a two-step process. The first step was to estimate the change in volume of groundwater flows while the second step was to estimate the monetary value of this change in volume.

Estimating additional groundwater from rainfall due to bush control

- The Ministry of Agriculture, Water, and Forestry (MAWF) currently assumes an average groundwater recharge rate across the entire country of 1% of Namibia's rainfall volume. This would mean that there are currently groundwater inflows of more than 1 billion m^3 per year in Namibia's identified bush-encroached areas.
- Data on responses of groundwater recharge rates to bush control are limited. This study took a conservative estimate of a rise in the recharge rate to 2% to be used in the central case.

→ If 5% of the 15.8 million targeted hectares were thinned per year and groundwater recharge rates improved linearly, bush control could result in additional groundwater recharge of just over 600 million m^3 per year after 21 years.

Valuing the increase in groundwater volume

For valuation purposes, the additional groundwater that would be used for the increased number of cattle had to be subtracted from the annual additional groundwater recharge. Over the 25-year horizon, a potential net groundwater recharge of approximately 214 million m^3 was calculated.

→ The implicit cost of water (based on data from NamWater) was then applied to the additional recharge volumes per year. An estimate of **N$ 51.6 billion (USD 4.0 billion)** for the discounted potential net benefit over the 25 year horizon was calculated.

Sensitivity analysis

Key variables, namely rainfall and the change in recharge rate, were varied in order to observe their impacts on the estimated benefit. It was found that the estimated benefits ranged from a low of N$ 25.2 billion (USD 2 billion), when the groundwater recharge rate only increased to 1.5%, to a high of N$ 104.4 billion (USD 8.2 billion), when the recharge rate increased to 3%. Changes in rainfall had a lesser impact, with estimated potential benefits ranging from N$ 41 billion (USD 3.2 billion), when average rainfall was 20% lower, to N$ 62.2 billion (USD 4.9 billion), when average rainfall was 20% higher.

Limitations and risks

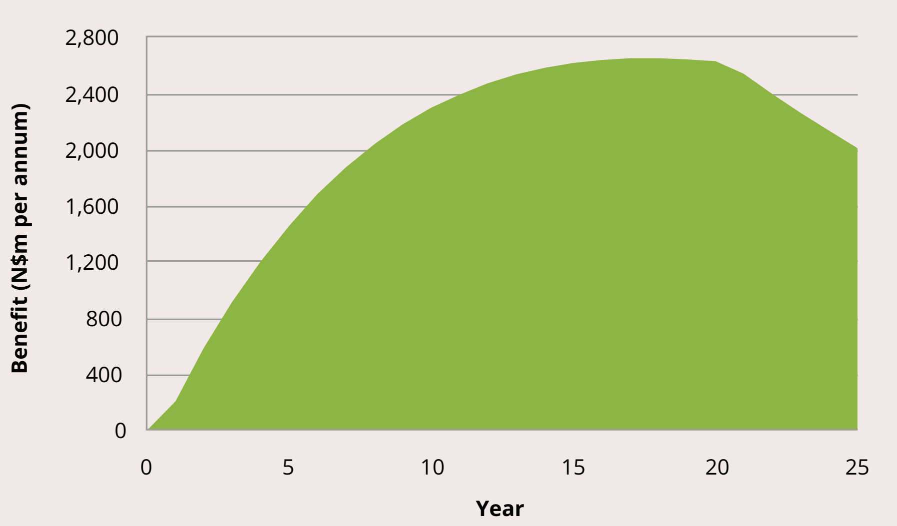
- The impact of bush control on groundwater recharge rates needs to be further researched, as the current data is very constrained in terms of location and timing. The estimate of an increase in recharge from 1% to 2% of rainfall is conservative, but there is little data to support it. Furthermore, recharge rates would be highly variable in different locations, depending on morphology and geology.
- The cost to increase capacity has been drawn from just one project, as cost data for projects in other regions were unavailable.
- A key risk is that if bush control is not carried out with good environmental management practices, it could increase soil erosion, which has the potential to increase vulnerability of groundwater resources.

Utilisation of biomass

There are several options for the utilisation of biomass from bush control. Some are already established in Namibia, such as firewood, charcoal production and crafts. Others are still being established or are yet to enter the market, such as

CHART 4

Potential benefit of increased groundwater recharge



electricity generation, construction and industrial materials or animal feed.

The utilisation options are aggregated and do not take into account trade-offs, also in terms of monetary benefits. Under the key assumptions and based on Zimmerman and Joubert (2002) and Honsbein et al. (2009), Namibia will not have the capacity to utilise the entire biomass available until the initial round of bush control has been completed (Year 21). However, between Year 21 and Year 25, depending on re-growth parameters, demand may exceed supply. Therefore, it would be beneficial if biomass could be stored in early years for later use.

If a sustainable bush-harvesting strategy is pursued (i.e. allowing bushes to grow back in order to re-harvest rather than aiming for permanently lower bush densities), this would increase the long-run supply of biomass for utilisation. However, this would come at the detriment of livestock carrying capacities and groundwater recharge, and likely other benefits, such as tourism and biodiversity.

Charcoal

Namibia currently produces an estimated 100,000 – 120,000 tonnes of charcoal per year (Ministry of Industrialisation, Trade and SME Development, 2017). The study assumes that this production would have been maintained without the specific programme of bush control in bush-encroached zones. Therefore, the value of 100,000 tonnes of production each year cannot be considered a benefit of bush control. However, if harvesting for charcoal production shifts from tree sources in vulnerable areas, this would represent a benefit in form of avoided cost.

Valuing

- The study assumes that production of charcoal will increase above the 100,000 tonnes by 25,000 tonnes per year, using biomass from bush thinning, until it reaches 300,000 additional tonnes (an increase to 300%) by the end of the twelfth year, and then plateaus.
- These volumes are multiplied by the current real average wholesale price of charcoal of N$ 1,600 (USD 126) per tonne.

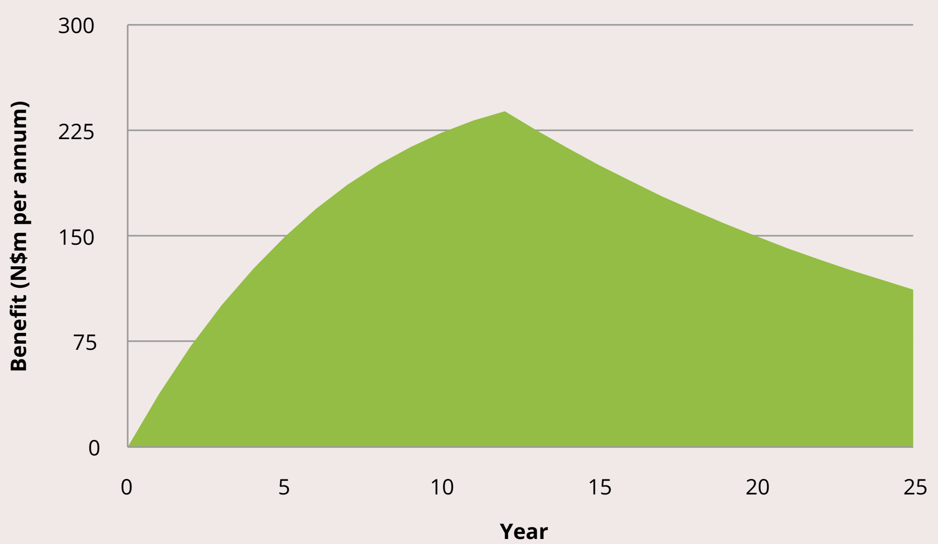
→ The discounted potential benefit was estimated at **N$ 4.1 billion (USD 0.3 billion)** over the 25 year horizon.

Sensitivity analysis

The price of charcoal was varied and it was found that the estimated benefits ranged from a low of N$ 3.2 billion (USD 0.3 billion), when the price was 20%

CHART 5

Potential benefit of increased charcoal production



Charcoal production

lower, to a high of N$ 4.9 billion (USD 0.4 billion), when the price was 20% higher.

Limitations and risks

Namibia currently exports a significant proportion of its charcoal to Europe. Increases in demand from Europe, the expansion of Namibia's market share, or entry into new markets, such as the Near, Middle, and Far East, may all increase demand for Namibian charcoal. Competition from other sources may reduce the demand for Namibian charcoal.

Firewood

Current demand for firewood in Namibia is estimated at 550,000 tonnes per year (Development Consultants for Southern Africa, 2015). The study assumes that this production would be maintained, but that the supply of firewood from encroacher bush would offset wood from non-encroacher bush.

Valuing

- From a base of zero additional tonnes in Year 0, it is assumed, that 100,000 tonnes of non-encroacher firewood production would be offset in Year 1, with further offsets of 5,000 tonnes increments each year, until it reaches an offset of 175,000 tonnes by Year 16, then plateaus. Additional firewood production starts at 5,000 tonnes in Year 2 and increases until it reaches 75,000 additional tonnes by Year 16, then plateaus.
- The additional volumes were multiplied by the real retail price of firewood of N$ 1,700 (USD 133.9) per tonne. The offset volumes were multiplied by 10% (the rough difference between fair trade and standard prices) of the retail price of firewood.

→ The discounted potential net benefit was estimated at **N$ 1.2 billion (USD 94.5 million)** over the 25 year horizon.

Sensitivity analysis

The price of firewood was varied in order to observe the impact on the estimated benefit. It was found that the estimated benefits ranged from a low of N$ 949 million (USD 74.7 million), when the price was 20% lower, to a high of N$ 1.4 billion (USD 110.3 million), when the price was 20% higher.

Limitations and risks

The forecasts for demand of firewood and the amount that would be offset are not based on robust data due to unavailability.

CHART 6

Offsetting and additional firewood production due to bush control

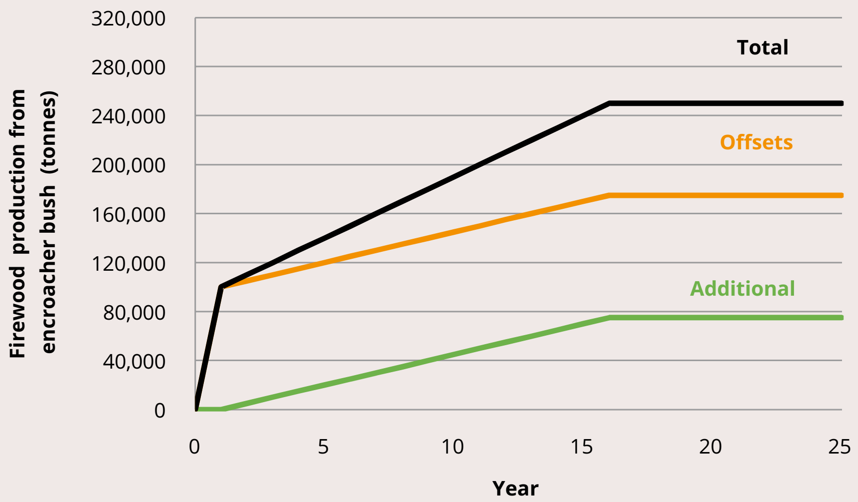
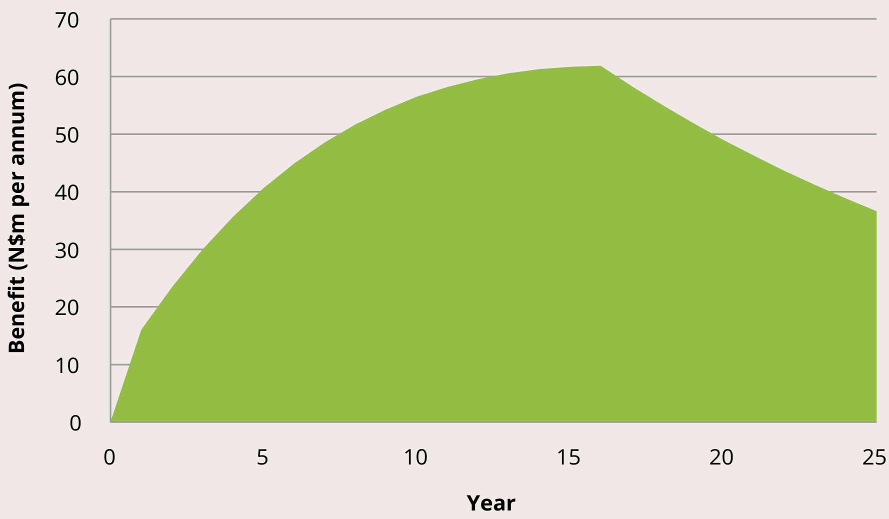


CHART 7

Potential benefit of increased firewood production



Electricity generation

Our analysis of the potential benefits of electricity generation is based on scenarios outlined in the *"Prefeasibility Study for Biomass Power Plant, Namibia: Power Plant Technical Assessment"* by NamPower in 2012. The development of ten 5 MW plants, three 20 MW plants using grate combustion with steam turbine, with the additional energy input of heated air, and three 20 MW plants using grate combustion with steam turbine, with no additional energy input was envisaged.

Valuing

- It is assumed that no plants would be operational in the first three years. Then plants would go into production successively. Capacity would reach 170 MW by Year 16.
- The current average tariff of electricity of N$ 1.28 (USD 0.10)/kWh is multiplied by the total output (in kWh) to estimate the total revenue.

→ The discounted potential net benefit was estimated at **N$ 10.6 billion (USD 0.8 billion)** over the 25 year horizon.

Sensitivity analysis

The forecast for an increase in capacity to 170 MW would require political support and significant investments by both the public and private sectors. A slower escalation, with peak capacity of only 110 MW (by Year 19) would result in an estimated benefit of N$ 7.3 billion (USD 0.6 billion).

NamPower estimates the breakeven price for biomass-fuelled electricity to equal N$ 2.00 (USD 0.16) to N$ 2.20 (USD 0.17)/kWh. This would be significantly higher than the current electricity tariff of around N$ 1.28 (USD 0.10)/kWh. It is therefore reasonable to expect that the government would have to subsidise electricity. Consequently, the net economic value of the additional electricity supply could be much lower. If the net economic value was 20 % lower, the benefit is estimated at N$ 8.5 billion (USD 669.5 million) over the 25 year horizon.

Limitations and risks

- There is a significant risk that the envisaged capacity will not be reached. There is no guarantee that there will be enough support and investment.
- Changes in the plant technology or different types of plants may alter the woodchips requirements.

Residual biomass as mulch

Many studies (Zimmermann, I., Joubert, DF. and Smit, GN., 2008; Joubert, D.F. and Zimmermann, I., 2002) recommend that some of the thinned biomass is left on the ground to return nutrients to the soil and provide protection for new grasses. Twigs and leaves are not suitable for charcoal, electricity or firewood production. Thus, they are preferable to be left as residuals. Smit et al. (2015) provide estimates of leaf and twig mass to woody mass in different encroacher bushes. The study takes an estimate of 15 % from this.

CHART 8

Electricity generation from thinned biomass

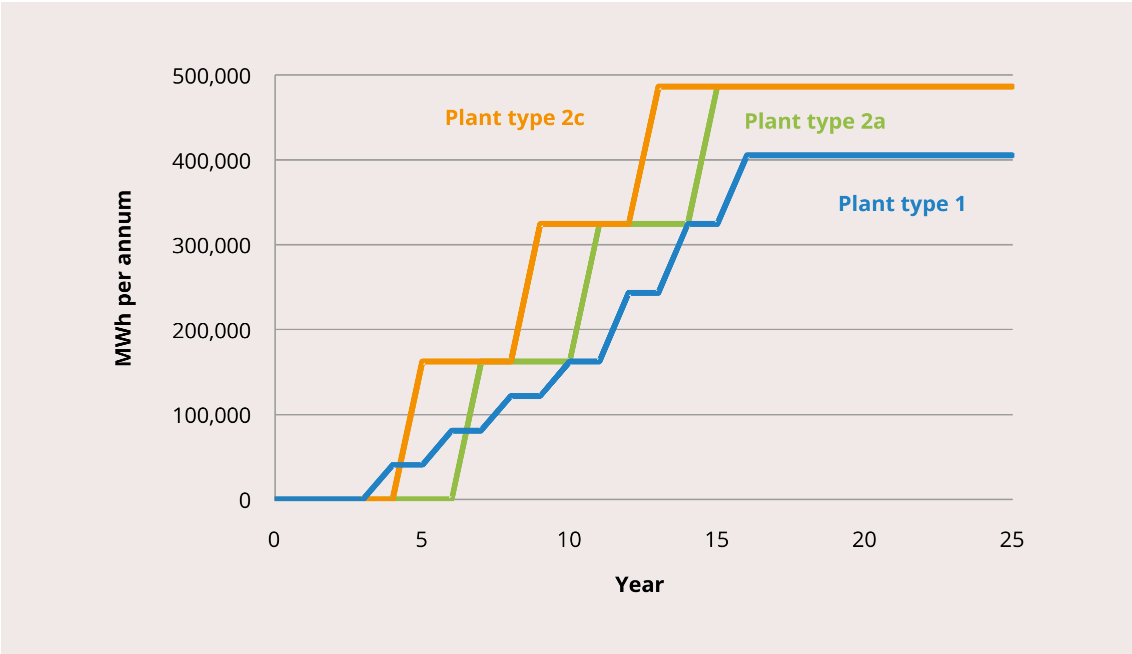
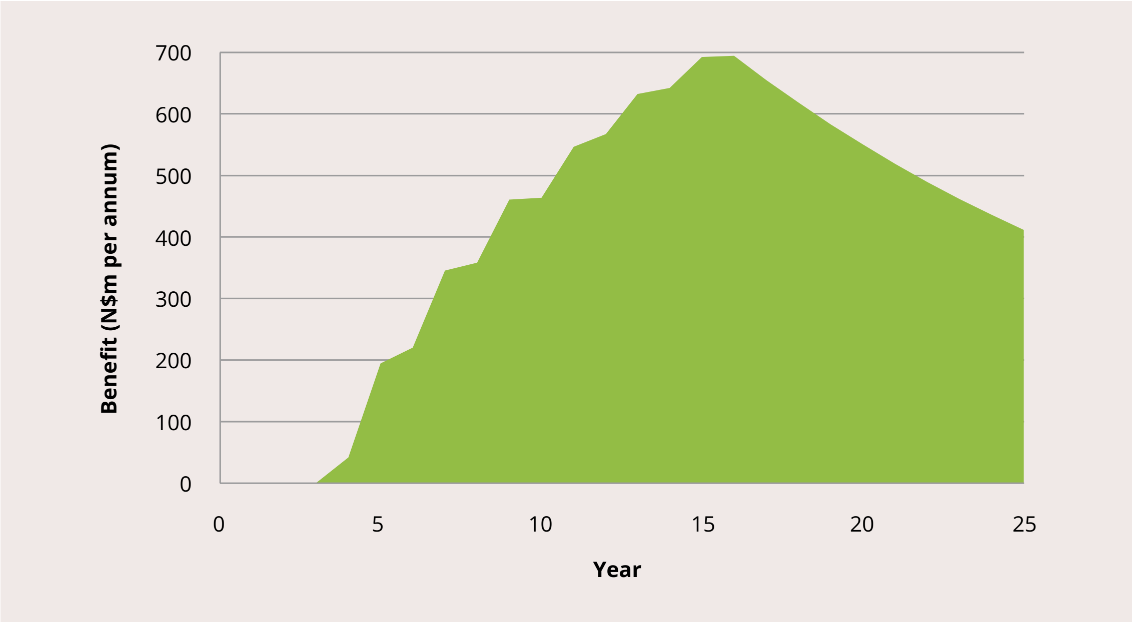


CHART 9

Potential benefit of increased electricity generation



Valuing

- To value the benefits of the residual biomass that is left on the ground, the price for mulch was used. For a cubic metre of mulch in South Africa, the price is R130 (=N$ 130.2 (USD 10.3)). A weight-to-volume estimate of 400 kg/m^3 was used to arrive at a price of N$ 325 (USD 25.6)/ tonne of residual biomass.
- The volume was then multiplied by this price to estimate the value of the residual biomass left on the ground after bush control.

→ The discounted potential net benefit was estimated at **N$ 2.1 billion (USD 0.2 billion)** over the 25-year horizon.

Sensitivity analysis

The value of the residual biomass was varied in order to observe the impact on the estimated benefit. It was found that the estimated benefits ranged from a low of N$ 1.7 billion (USD 0.1 billion), when the price was 20% lower, to a high of N$ 2.5 billion (USD 0.2 billion), when the price was 20% higher.

If the proportion of the weight of leaves and twigs to woody biomass was only 10%, or if the equivalent of only 10% was left on the ground, rather than 15%, the benefit was estimated at N$ 1.4 billion (USD 0.1 billion).

Limitations and risks

In order to ease operations, operators might extract all biomass, rather than leaving a selected proportion behind.

Other use opportunities

The increased supply of woody biomass could also have other uses including:

- Wooden crafts which are traditionally made in Namibia, thus bush control could support increases in production.
- Construction materials can also be produced from thinned biomass, including poles, wood cement, medium-density fibre boards, wood-plastic composites, and wooden frames. Poles are currently produced at an estimated 334,000 m^2 per year, but are also imported. The other materials appear to be either niche industries or currently not produced in Namibia. Increased supply of biomass could support growth in these industries.
- Biomass from encroacher bush can also be used as an input into animal feed. Tambuti, for example, a mixed-use farm in the Otavi area, already produces its own animal feed from thinned biomass on its property and is likely to sell to other farmers. Estimates are that between 50% and 85% of a tonne of animal feed

CHART 10

Residual biomass from bush control

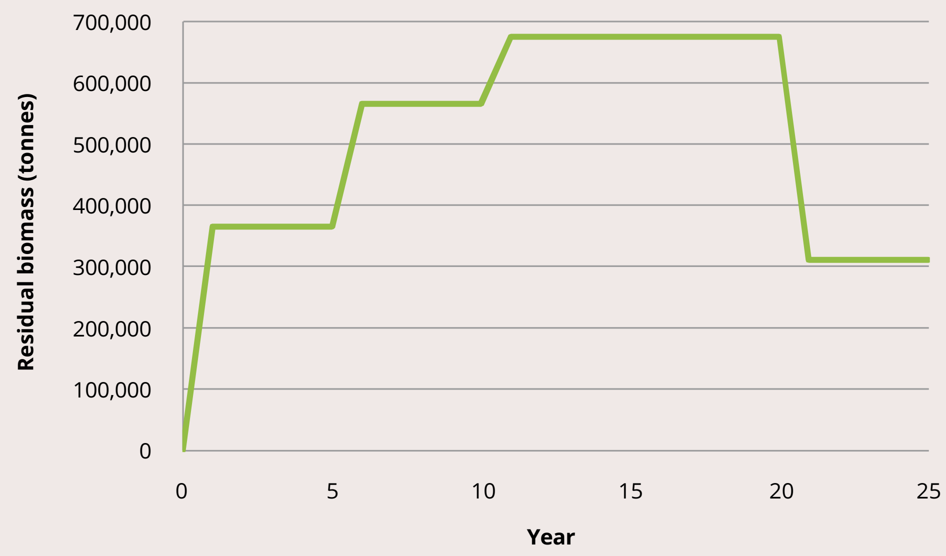
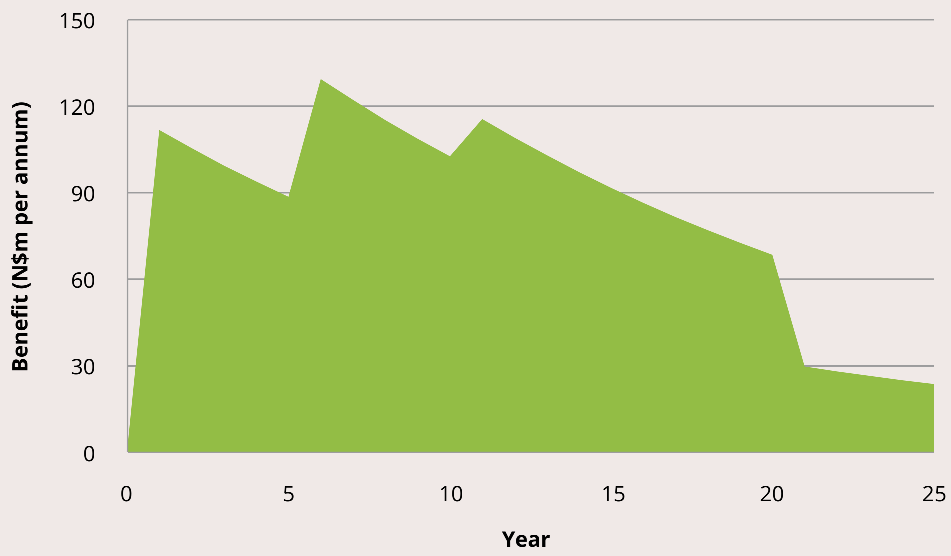


CHART 11

Potential benefit of residual biomass



can come from woody biomass, with a market price of between N$ 300 (USD 23.6) to N$ 325 (USD 25.6) per 40 kg bag.

- Namibia Breweries Limited has piloted the use of a woodchip boiler for the generation of process heat. This technology is already well-established in Europe and elsewhere and could be expanded into other industries, such as meat and fish production.
- Bush banks, where biomass from bush control is stored and can be sold from, are enterprises that could potentially increase ease of access to wood, supporting growth in the above industries.

Carbon sequestration

Studies (Wessman et al., 2004; Hudak et al., 2003; Blaser et al., 2014) assessing the impact of changes in land cover relating to bush encroachment on carbon sequestration have mixed results. However, evidence indicates that there is a broadly positive impact from bush encroachment on soil carbon sequestration, but that it is likely to be location and context-specific. The values presented should be taken as only broadly indicative.

Valuing

Due to Namibia's relatively low levels of soil organic carbon (SOC), the study assumes that the capacity of the soil to sequester carbon is only reduced in the year of bush control, rather than annually. The inverse of these estimates are applied as an approximation of the benefits/costs in terms of carbon sequestration when bush thinning. The impacts are then transformed into tonnes of CO_2 per hectare sequestered.

The calculated estimate is a reduction in tonnes of CO_2 sequestered per hectare per year of 0.77. The estimate of total net change in CO_2 emissions in soil carbon sequestration from bush thinning equals 8.1 million t CO_2.

Several different values have been attached to traded carbon offsets. The study attaches a value of N$ 60 (USD 4.7)/tCO_2e[5] which is currently being used for the National Integrated Resource Plan review.

→ Based on these estimates the net present value of carbon sequestration represents a cost of **N$ 278.6 million (USD 21.9 million)** in 2015 prices over the 25 year time horizon.

There will be further impacts on net carbon sequestration in Namibia based on how the thinned material and/or land are used. Two key issues are the use of thinned material to produce electricity, and the exploitation of the anticipated increased carrying capacity of land to farm more cattle.

The impact of new electricity generation on net carbon sequestration in Namibia depends on whether this energy is additional to or replaces other grid sources, and whether the harvesting of bush for this purpose prevents the burning of bush-encroached areas.

While electricity generation from biomass sources would be unlikely to immediately displace grid energy, the development of such power plants would relieve pressure on Namibia's supply and mean that more polluting sources could be avoided. However, it is not clear whether the project would prevent the burning of bush encroached areas. Consequently, the estimates of avoided emissions from displacing grid energy are favoured.

A net change in CO_2 emissions was calculated to amount -9.91 million t CO_2.

→ Based on the scenario of three types of power plants potentially **avoided cost of N$ 227.9 million (USD 18.0 million)** are estimated as offsets.

A major benefit of bush control is the increase of the carrying capacity of rangeland, which can in turn be used to produce more beef from cattle. However, greater numbers of cattle will increase greenhouse gas emissions. An additional kilogram live-weight of cattle is estimated to contribute an additional 11.93 kgCO_2e per year[6]. Over the 25 year study period, this would correspond to total additional emissions of 42.3 million tCO_2e.

→ The estimation over the 25 year study period yields a present value of **costs of N$ 982.0 million (USD 77.3 million)** from livestock emissions.

Sensitivity analysis

Namibia does not appear to have clear guidance on how to value carbon emissions for policy appraisal at a domestic level. The central case, using the Namibian offset value, would result in a net cost of N$ 1.0 billion (USD 78.8 million) over the 25-year

5 *Although the value is not based on an actual market, it is very close to the average price of voluntary carbon offsets traded in markets (USD 3.8/tCO_2e), which gives it a measure of robustness.*

6 *http://beefandlamb.ahdb.org.uk/news/livestock-and-the-environment/livestock-and-climate-change-the-facts/.*

horizon. The central estimate of the social cost of carbon (SCC) of a tonne of CO_2 emitted in 2015 is approximately USD 40 in 2014 prices (USD 40.1 in 2015 prices), rising to USD 77 by 2050. Using the SCC, the net cost would equal almost twelve times that of the Namibian offset value, amounting to N$ 12.3 billion (USD 1.0 billion).

Tourism

It is commonly understood that dense bush can have negative impacts on both consumptive (e.g. hunting) and non-consumptive (e.g. wildlife viewing) tourism. However, no research has been undertaken on the quantitative impacts of bush thinning on tourism and the resultant economic benefits.

Valuing

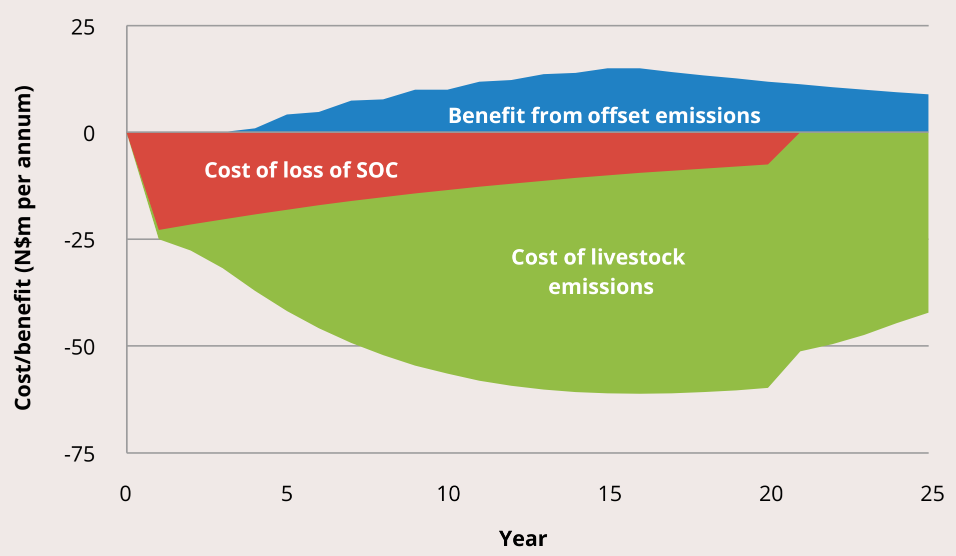
In order to provide a very rough estimate, the potential benefits from hunting operations are assessed.

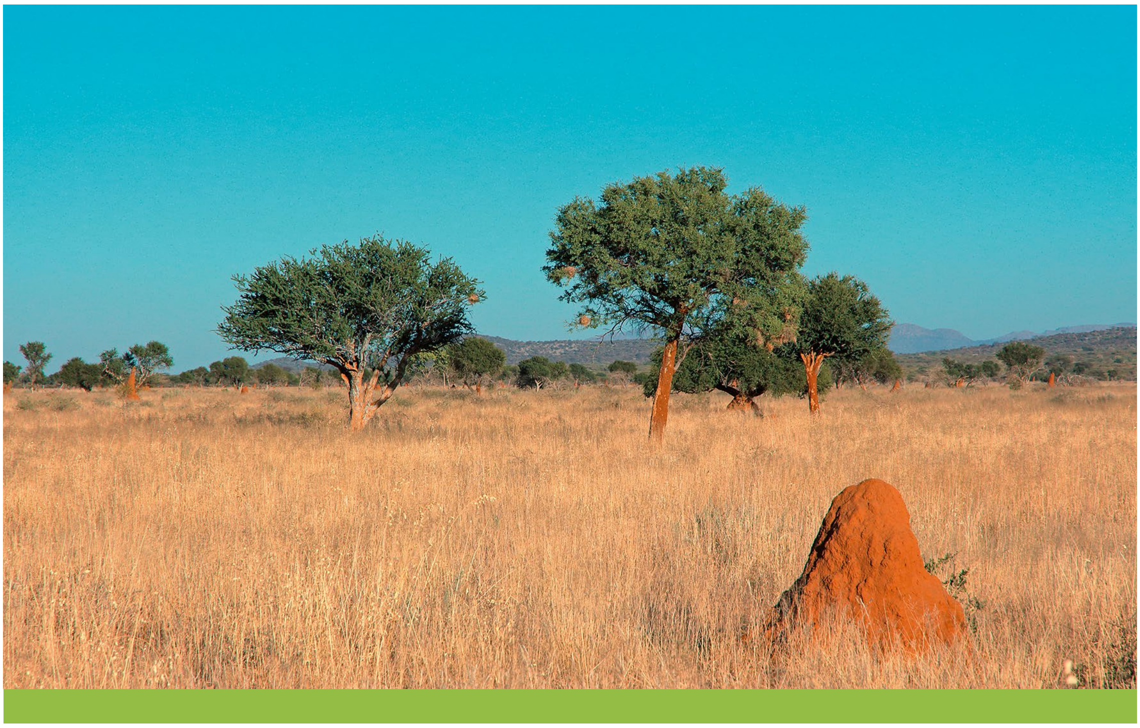
- Gross income from wildlife-based uses for mixed use farms ranges from approximately N$ 74/ha (USD 5.8/ha) to N$ 170/ha (USD 13.4/ha), whilst a game-only farm generates around N$ 478/ha (USD 37.6/ha) (Venter, 2015).
- Bush control could mean that such operations become increasingly viable over a wider area of land as wildlife carrying capacities increase and the hunting experience is improved. Assumptions include that 10% of thinned land is used for hunting and cattle farming as well as a 1 year delay between bush control and the hunting operation commencing.

→ Using an average gross income per ha from wildlife based uses (N$ 129.6/ha (USD 10.2/ha)), this would result in potential real benefits of around N$ 9.1 million (USD 0.7 million) (discounted, on mixed use farms) in 2017. Aggregating these benefits over a 25 year period would subsequently result in total discounted benefits of **N$ 120.9 million (USD 9.5 million)** (2015 prices). This should be seen only as a very broad first estimate of potential benefits due to a significant lack of data. Therefore, the value is not included in the cost-benefit analysis of the central case.

CHART 12

Cost/benefit of loss of soil organic carbon, additional livestock emissions and offset emissions





Area virtually cleared of all woody plants and kept open by constant follow-up measure to avoid re-establishment of woody plants.

Valuation of bush control costs

Harvesting cost

Five methods of mechanical bush control were included in the analysis, along with the use of arboricides. Only manually-applied arboricides were considered, as there is considerable uncertainty as to whether aerial arboricide application will be legal in Namibia in the future.

Valuing

90% of bush control was assumed to be carried out manually, while 10% was assumed to be carried out using arboricides.

→ The total discounted cost of bush control over the 25-year time horizon was estimated at **N$ 26.9 billion (USD 2.1 billion)**. 98.5% of this cost is accounted for by the mechanical methods, even though they are only used for 90% of the harvest.

Sensitivity analysis

If the cost of bush control operations was 20% higher, the total real cost is estimated to increase by more than N$ 5 billion (USD 393.8 million) to N$ 32.2 billion (USD 2.5 billion) (discounted). If the cost of bush control was 20% lower, e.g. due to economies of scale and optimisation of processes, the total real discounted cost could be as low as N$ 21.5 billion (USD 1.7 billion).

Limitations and risks

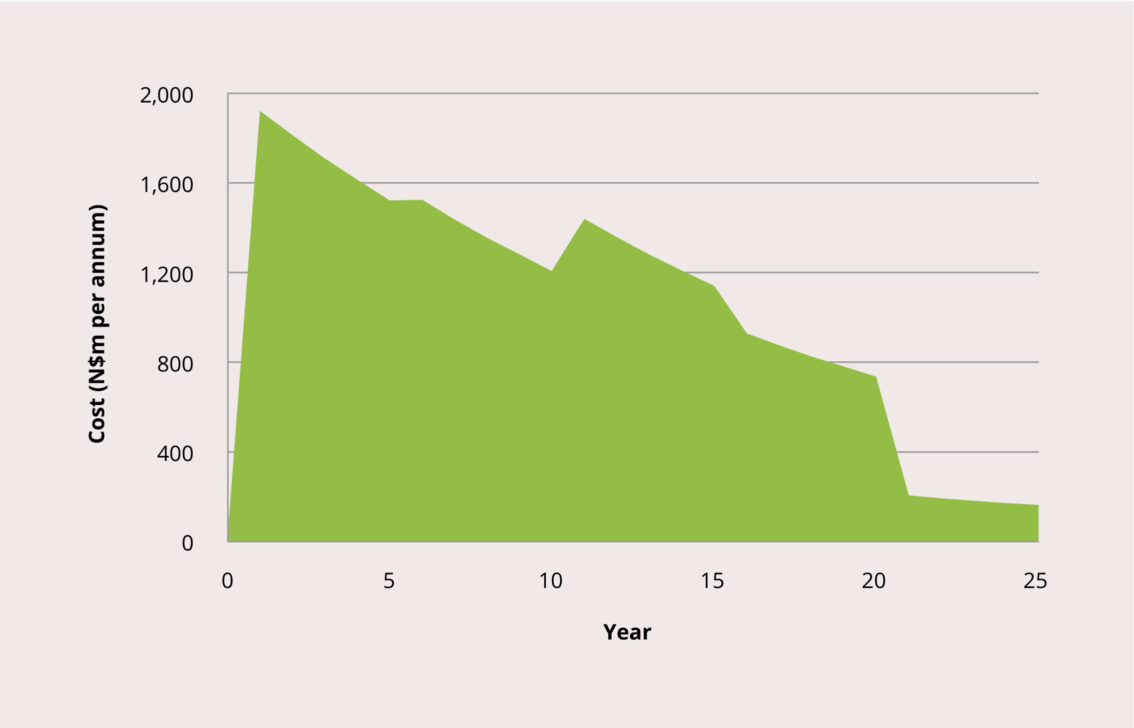
- The proportion of mechanical to arboricide methods (90:10) is a broad assumption, for which changes would have a significant effect on the total cost.
- There is also a risk that not enough bush control operations could be mobilised at the beginning of the programme. This would mean slower improvement in other sectors, such as livestock production and groundwater recharge, but it would not necessarily alter the costs of bush control.

Environmental costs

In addition to the direct costs, bush control causes potential environmental costs, which have not been quantified here. Mechanical methods disturb the soil, leading to erosion and greater runoff. This could potentially constrain groundwater recharge. Arboricides potentially have a negative influence on the germinability of non-encroaching species, therefore potentially affecting the quantity and composition of the seedling bank, which is the major route for regeneration in this semi-deciduous forests. Seedling diversity, density and distribution and species richness are also largely a function of

CHART 13

Potential harvesting cost of bush control



Mechanised harvesting of encroacher bush adult diversity, potentially affected by the use of arboicides as well (Honsbein et al., 2012).

Harvesting bush also removes nutrients, such as carbon and potassium from the system, which can represent a significant cost. The environmental costs are assumed to escalate as the size of the bush control operation increases.

Social costs

There are also potential social costs to be considered. If temporary workers are employed for bush thinning work on farms, social costs could include the spread of HIV-AIDS and other diseases, crime, and impacts on local services.

Employment costs

Employment is technically considered a cost in cost-benefit analysis. However, additional employment can also offer benefits, particularly in a country like Namibia where unemployment is generally high and youth employment is even higher. The social benefits of employment can include income security and higher living standards, improvements in health and education, decreased crime and drug use, decreased family disruption, and so on. There are also economic benefits via multiplier effects – the income that workers earn will be mostly spent within Namibia, stimulating economic activity.

→ It is estimated that under the assumptions of the above number of operations, the bush control programme could employ in excess of 10,000 people during the initial round of 25 years. For the large commercial scale operation, 0.6 workers need to be employed for every 1,000 tonnes of harvest per year. For small-scale manual operations, the estimate is 12.5 workers. Additional jobs would also be provided during follow-ups. However, when the initial round of bush control is complete, there would be a significant fall in employment as the harvest volume drops.

Cost-benefit analysis at national level

Central case analysis

In the central case (67% of bush to be harvested, 5% of total area to be targeted each year over a 25 year period), the estimated potential discounted net benefits of bush control add up to N$ 48.0 billion (USD 3.8 billion) over 25 years. This value represents the sum of all potential benefits and costs across all use and thinning options.

The central case is based on the following assumptions:

- Increase of carrying capacity by 100%
- Groundwater recharge increases to 2%
- Charcoal production increases by 300%
- Electricity generation capacity increase to 170 MW
- Firewood demand gradually increases and will reach 75,000 by Year 16
- Residual mulch increase to 15% of total harvested biomass
- Reduction of CO_2 to 77 tonnes/ha/year
- Harvesting costs amount to N$ 26.9 billion (USD 2.1 billion)
- SOC emissions increase to 3.3 million tCO_2e

TABLE 4

National cost/benefit analysis – central case

Variable	Amount mN$ (mUSD)
Benefits	76,137.91 (5,996.72)
Grazing land (cattle carrying capacity)	6,371.66 (501.84)
Groundwater recharge	51,609.54 (4,064.83)
Biomass utilisation	
Charcoal	4,060.59 (319.82)
Electricity	10,572.07 (832.67)
Firewood	1,186.17 (93.42)
Residual biomass	2,110.00 (166.19)
Carbon offsets	227.88 (17.95)
Costs	28,116.98 (2,214.53)
Bush thinning	-26,856.42 (-2,115.25)
Carbon	
Loss of soil organic carbon	-278.55 (-21.94)
Livestock emissions	-982.01 (-77.34)
NET BENEFIT	**48,020.94 (3,782.19)**

Partial sensitivity analysis

Partial sensitivity analysis involves taking the aggregated central case and then varying a single assumption or estimate, while holding all others constant, to determine the NPV's sensitivity to that specific variable. Variables which have a relatively insignificant effect on the NPV were not varied.

Livestock

If the carrying capacity was tripled rather than doubled, we could expect an extra N$ 4.2 billion (USD 330.8 million) in benefits, despite increased costs from livestock emissions. If carrying capacity only increased by 50%, the Net Present Value (NPV) would likely fall by around N$ 2.1 billion (USD 165.4 million).

Groundwater

Variation in groundwater recharge rates appears to have the most significant effect on the NPV. If it is assumed that recharge rates would increase from the current 1% to 3% of rainfall in bush-encroached zones, rather than 2%, the NPV would more than double to more than N$ 100 billion (USD 7.9 billion). The study did not include a downside variation as 2% is already quite a conservative assumption.

Electricity generation

If the capacity of biomass power plants only reached 110 MW, this would reduce the NPV by an estimated N$ 3.3 billion (USD 259.9 million). This would be partly due to a reduction in the avoided cost of emissions.

Carbon sequestration

Carbon can be valued in a number of ways. The SCC takes into account economic damages associated with a small increase in carbon dioxide (CO_2) emissions, and is much higher than any current market rate (US EPA, 2015). Using the SCC (USD 40.1 in 2015 prices) to value carbon, the NPV would fall by an estimated N$ 11.3 billion (USD 890 million) to N$ 36.8 billion (USD 2.9 billion).

Bush control cost

A 20% increase in bush control costs is estimated to reduce the NPV by N$ 5.4 billion (USD 425.3 million), while a 20% decrease is estimated to increase the NPV by the same amount.

Discount rates

One of the most important variables to undergo sensitivity analysis is the discount rate, as the choice of rate can be quite subjective and it can significantly affect the final outcome. In the central case, a real discount rate of 6% per year was used. This is consistent with the real discount rate used in the Wildlife Resource Accounts of Namibia.

A variation in discount rates changes the NPV. The NPV is estimated at only N$ 18.5 billion (USD 1.5 billion) at a discount rate of 12%, but at N$ 67.4 billion (USD 5.3 billion) at a discount rate of 4%. The net benefits tend to decrease as the discount rate rises, because the benefits of bush control tend to be weighted towards the middle and end of the time horizon and are consequently more heavily discounted.

Scenario analysis

In this section, three key scenarios are explored to establish the range of costs, benefits, and net benefits that could be expected under different assumptions and outcomes.

Scenario 1 : 33 per cent bush control

A key alternate scenario is a programme of bush control, which only reduces bush density by 33%, rather than 67%. In this scenario, an estimated potential net benefit of **N$ 24.9 billion (USD 2.0 billion)** is projected.

Difference to the central case:

- Carrying capacity increases by 50% (rather than 100%) which reduces groundwater used for livestock and emissions from livestock compared with the central case.
- Groundwater recharge increases to 1.5% of rainfall (rather than 2%).
- Charcoal production is halved compared with the central case.
- The capacity of electricity generation increases to 80 MW by Year 13, rather than 170 MW by Year 16 in the central case.
- This correspondingly reduces the benefits from carbon offsets.
- Firewood production is halved compared with the central case.
- Residual biomass is halved.
- Bush control costs are halved.
- Loss of SOC is halved.

Scenario 2: Best case

In the best case scenario, the estimate shows that potential net benefits could be as high as **N$ 111.9 billion (USD 8.8 billion)**.

Difference to the central case:

- Carrying capacity increases by 200% (rather than 100%), but this increases groundwater used for livestock and emissions from livestock compared with the central case.
- Groundwater recharge increases to 3% of rainfall (rather than 2%).
- Carbon is valued at N$ 60 (USD 4.7) per tonne as in the central case.
- Charcoal production is the same as the central case (as the harvest of biomass does not increase), but the price is 20% higher.
- The benefits from electricity generation are unchanged compared with the central case, as we believe that there is largely downside risk to this estimate.
- This means that the benefits from carbon offsets are unchanged.
- Firewood production is the same as the central case, but the price is 20% higher.
- Residual biomass value is 20% higher.
- Bush control costs are 20% lower.
- Loss of SOC is unchanged from the central case.

Scenario 3: Worst case

In the worst case scenario, the estimate shows that the potential net benefit could be as low as **N$ 28.9 billion (USD 2.3 billion)**.

Difference to the central case:

- Carrying capacity increases by 50% (rather than 100%), but this decreases groundwater used for livestock and emissions from livestock compared with the central case.
- Groundwater recharge is unchanged from the central case, as this is already a very conservative estimate.
- The SCC is used to value carbon.
- Charcoal production is the same as the central case (as the harvest of biomass does not increase), but the price is 20% lower.
- The capacity of electricity generation increases to 110 MW by Year 19, rather than 170 MW by Year 16 in the central case.
- This means that the benefits from carbon offsets are lower.
- Firewood production is the same as the central case, but the price is 20% lower.
- Residual biomass volume is 10% rather than 15%.
- Bush control costs are 20% higher than in the central case.

CHART 14

Cost and benefits in the central, best and worst case scenario

CHAPTER

05 Otjozondjupa Case Study

The Total Economic Valuation (TEV) study framework, which was used in the national assessment above valued the potential costs and benefits for ecosystem services as well as the direct costs of bush control operations. The Otjozondjupa case is also based on this framework, but goes a step further: it factors in additional use options and estimates the financial costs involved in unlocking the ecosystem service benefits – such as the costs for purchasing additional livestock after bush control. The case study therefore provides a holistic assessment of economic opportunities for the Otjozondjupa region of Namibia.

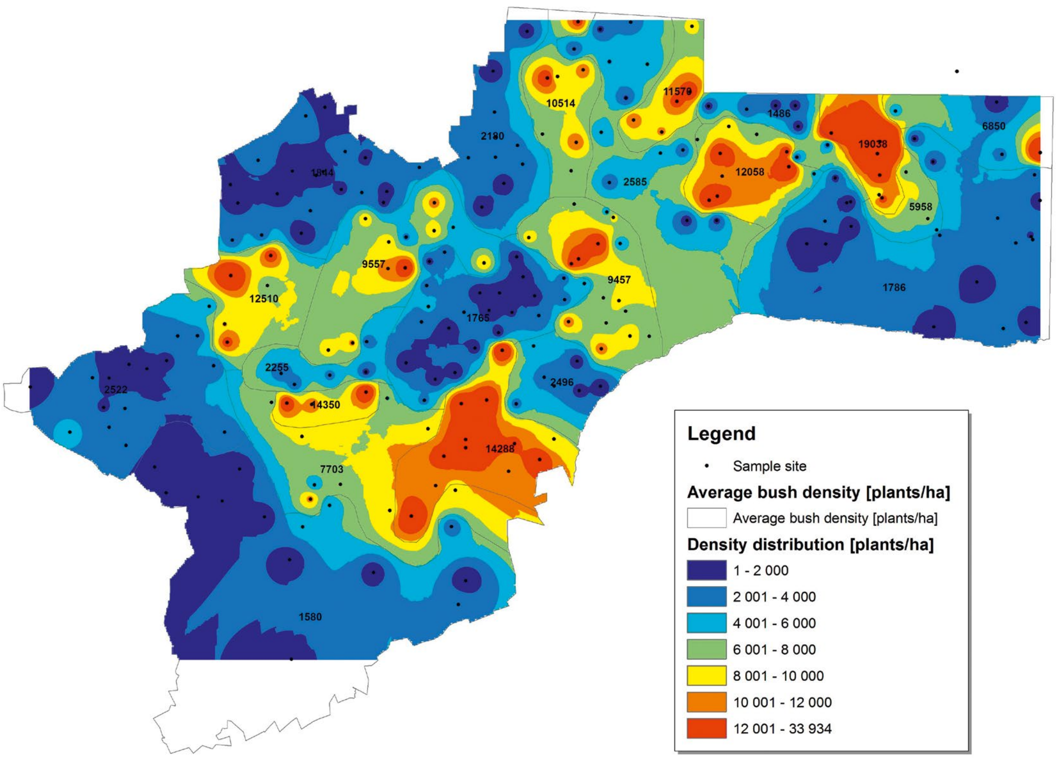
Bush encroachment in Otjozondjupa

In Otjozondjupa, Namibia's fourth biggest region at more than 10.5 million hectares, bush encroachment affects the majority of the land area (Hengari, 2016). *Acacia mellifera* and *Terminalia cericea* are the dominant encroacher species in this region. The highest recorded density was over 25,000 bushes per hectare in the northeast of the region.

Bush encroachment affects multiple ecosystems within Otjozondjupa, including the Highland

FIGURE 5

Bush density in Otjozondjupa region



Source: Katharina Dierkes, CIAT 2016

Acacia Savannah, Northern Kalahari Savannah, Karstveld, Dry Kalahari Woodlands, and small parts of the Western Highlands. It affects multiple land uses, but particularly commercial and communal agriculture and tourism.

Key assumptions

- 60% (more than 6.3 million hectares) of the bush-encroached area in Otjozondjupa could be targeted for bush control,
- 5% of this area could be thinned per year,
- density of dominant encroacher species would be reduced by 90%, leaving non-encroacher species untouched,
- an overall reduction in bush density across the region of 38.5%[7] can be achieved.

A time horizon of 25 years was chosen and real prices in Namibian dollar (base year 2015[8]) were used. This captures the 20 years spent on the initial bush control (i.e. without follow-ups or aftercare) and allows time for ecosystem services, such as grazing land for livestock production and groundwater recharge, to reach their new potential.

Valuation of key ecosystem services impacted by bush encroachment

Grazing land for livestock

Livestock farming, particularly cattle farming, is a significant land use, employment and income generator in Otjozondjupa. Between 2011 and 2015, Otjozondjupa accounted for an average of 16.9% (Directorate of Veterinary Services) of total cattle in Namibia.

Livestock carrying capacities have been drastically reduced, decreasing farmer incomes and profits. This has also compromised food security and nutrition, particularly in communal areas. Cattle farming is a traditional way of life for many people in Namibia. In addition to its economic value, it has cultural, heritage and symbolic value (Hengari, 2016).

The accepted rule of thumb is that a reduction of bush land to an optimal density of 33% would at least double the carrying capacity (De Klerk, 2004). This assumption was applied to the current stock of cattle, according to livestock census data, adjusted for the extent of bush thinned in the zone and by whether they were commercial or communal, above or below the veterinary cordon fence. Thus, it was assumed that following bush thinning of an area, it would take four years to reach the new carrying capacity in that area.

The average beef producer price for year 2015 of N$ 27.3 (USD 2.2)/kg (Meat Board of Namibia) was applied to the offtake (in kg) with a factor of 246.9 kg/head (based on FAO Namibian meat production data). The analysis showed that bush control could result in an additional N$ 277 million (USD 21.8 million) per year (undiscounted). The discounted benefit was estimated at N$ 1,139.3 million (USD 89.7 million) over the 25 year horizon. The Namibia Agricultural Union provided data on the production costs of a cow-ox cattle production system for a typical cattle farm. The discounted cost was estimated at N$ 933.2 million (USD 78.2 million) over the 25 year horizon. **The net benefit for additional cattle production was estimated at N$ 146 million (USD 11.5 million).**

The case study also needs to take into account the increase in wealth represented by the additional cattle. This can be realised by using an option value – at the end of the 25 year period, if the additional cattle were sold off, how much would this be worth? It was estimated that almost 170,000 cattle could be added to the herd. **Based on the Namibia Agricultural Union's model of herd dynamics, the total option value was estimated at N$ 215.7 million (USD 17.0 million) (discounted).**

However, it must be noted that overgrazing, particularly by cattle, is a key contributor to bush encroachment. Therefore, if a bush thinning programme is implemented, good rangeland management practices must be followed. This may mean that restocking livestock should not be to the numbers seen prior to significant bush encroachment or that more suitable and sustainable grazing strategies, which do not weaken grass systems over time, should be selected.

7 *In line with Smit et al. 2015 suggestion that only 30–35% of total available biomass should be harvested*

8 *An exception was made for the Social Cost of Carbon which escalated each year, as it has been forecasted by the US government*

Groundwater

Namibia is the most arid country in Sub-Saharan Africa and is highly dependent on groundwater. Bush encroachment increases the rate of evapotranspiration, reducing groundwater recharge rates. **The potential net benefit for additional sustainable extraction and use of groundwater was estimated at N$ 406.4 million (USD 32.0 million) (discounted).**

Wildlife viewing and game farming

Wildlife viewing is a significant tourism activity on private farms, in conservancies, and in protected areas in Otjozondjupa. The number of registered hunting farms covers approximately 1,248,300 ha, these include mixed-use farms (livestock production and hunting of game), private game farms (no hunting) with an estimated 183,000 ha and IUCN-listed protected areas with an estimated 38,600 ha. Trophy hunting is also an important source of revenue for private farms and conservancies, and the use and sale of game meat brings in revenue and improves nutrition and food security in rural areas. **The discounted benefit for wildlife viewing was estimated at N$ 22.7 million (USD 1.8 million), for trophy hunting and game products at N$ 202.0 million (USD 15.9 million).**

Charcoal production – Value addition

Carbon sequestration

Soil organic carbon (SOC) varies under different land cover. A shift from bush encroachment towards grasslands and lower bush density is estimated to result in a decrease in SOC on average. **Over 25 years, the discounted cost from the loss of SOC was estimated at N$ 64.4 million (USD 5.1 million).**

Greater numbers of cattle will increase greenhouse gas emissions; an additional kilogram live-weight of cattle is estimated to contribute an additional 11.93 kgCO_2e per year. **This can be valued using the Namibian carbon offset value, resulting in an estimated discounted cost of N$ 195.5 million (USD 15.4 million).**

Utilisation of biomass: Charcoal

According to the Charcoal Sector Growth Strategy, between 2013 and 2015, Namibia exported around 120,000 tonnes of charcoal per year and domestic demand was around 1,000 tonnes per year, resulting in total national production of around 121,000 tonnes per year. The Namibia Charcoal Association estimates that 60% of this is produced in Otjozondjupa, around the hubs of Grootfontein, Otavi, Okahandja, and Otjiwarongo. This means that Otjozondjupa currently produces 72,000 tonnes for export and 600 tonnes for domestic demand per year, in total 72,600 tonnes per year.

By Year 25, we estimate that an additional 198,459 tonnes of charcoal could be produced per annum and that 34,366 tonnes would be produced using encroacher bush rather than non-encroacher bush and trees. The additional (non-offset) volumes of charcoal produced were then multiplied by the current real average wholesale price of charcoal of N$ 1,600 (USD 126) per tonne. The offset volumes were multiplied by N$ 100 (USD 7.9) per tonne, the approximate difference between fair trade and standard wholesale prices of firewood.

The discounted benefit was estimated at N$ 2.5 billion (USD 0.2 billion) (2015 prices) over the 25 year horizon.

We take estimates from NCA (2016) for capex and opex for charcoal production which results in an estimated discounted cost of N$ 1.1 billion (USD 86.6 million) (2015 prices) over the 25 year horizon. **The potential net benefit for charcoal production was estimated at N$ 1.4 billion (USD 109.5 million) (discounted).**

Utilisation of biomass: Firewood

Firewood is the primary fuel source for many rural households and informal settlements in Namibia. Much of it is collected for own use or informally sold by roadsides and in markets, but some is retailed at supermarkets and petrol stations. It is assumed that a significant amount of firewood is collected from non-encroacher bushes and trees, which can have negative environmental impacts. Therefore, offsets and additional production quantities were valued. **In total, the discounted potential net benefit was estimated at N$ 633.9 (USD 49.9 million) over the 25 year horizon.**

Utilisation of biomass: Animal feed

Biomass from encroacher bush can be used as an input into animal feed. It can make up between 50–85% of animal feed, with supplements such as molasses. It is assumed that in bush controlled areas increased grass production would be sufficient and animal feed would not be required. Animal feed could be marketed to farms which have not been included in the bush control programme within Otjozondjupa, or in different regions, and which don't have sufficient fodder. **A discounted potential net benefit of N$ 734.7 million (USD 57.9 million) over the 25 year horizon is estimated.**

Utilisation of biomass: Power for Industry

Ohorongo Cement is Namibia's only cement-producing company and the plant is located near Otavi in Otjozondjupa. Ohorongo invested in a kiln that can process wood chips as well as coal (at a 1:1.6 ratio of tonnes of coal to woodchips) to generate energy for cement production. It aims to replace 75% of coal with woodchips but is currently restricted to only 50% of this capacity due to supply constraints.

Namibia Breweries has invested in a biomass boiler worth N$ 50 million (USD 3.9 million) for its Windhoek plant. This boiler will allow 3,100 tonnes of the current 3,600 tonnes of heavy fuel oil (HFO) used per year to be replaced by 7,500 tonnes of woodchips. This technology can be used in other industries, for example, in meat production. The study assumed that other similar conversions to biomass boilers could be realised in Otjozondjupa (e.g. manufacturing, mining and beverage), starting from Year 2 with a new conversion occurring every three years. This would result in a reduction in HFO use of up to 15,500 tonnes per year.

In total, replacing coal and HFO with woody biomass, according to the above examples, could result in a total discounted benefit of N$ 672.9 million (USD 53.0 million) and total discounted cost of N$ 171.4 million (USD 13.5 million). **Consequently, the potential net benefit of biomass generated power for industry was estimated at N$ 501.5 million (USD 39.5 million) (discounted).**

Utilisation of biomass: Electricity generation

The development of three 5 MW plants (type 1), two 20 MW plants using grate combustion with steam turbine, with the additional energy input of heated air (type 2a), and two 20 MW plants using grate combustion with steam turbine, with no additional energy input (type 2c) was envisaged along an assumed timeline (NamPower, 2012). **The potential net benefit for biomass electricity generation was estimated at N$ 3.4 billion (USD 0.3 billion) (discounted).**

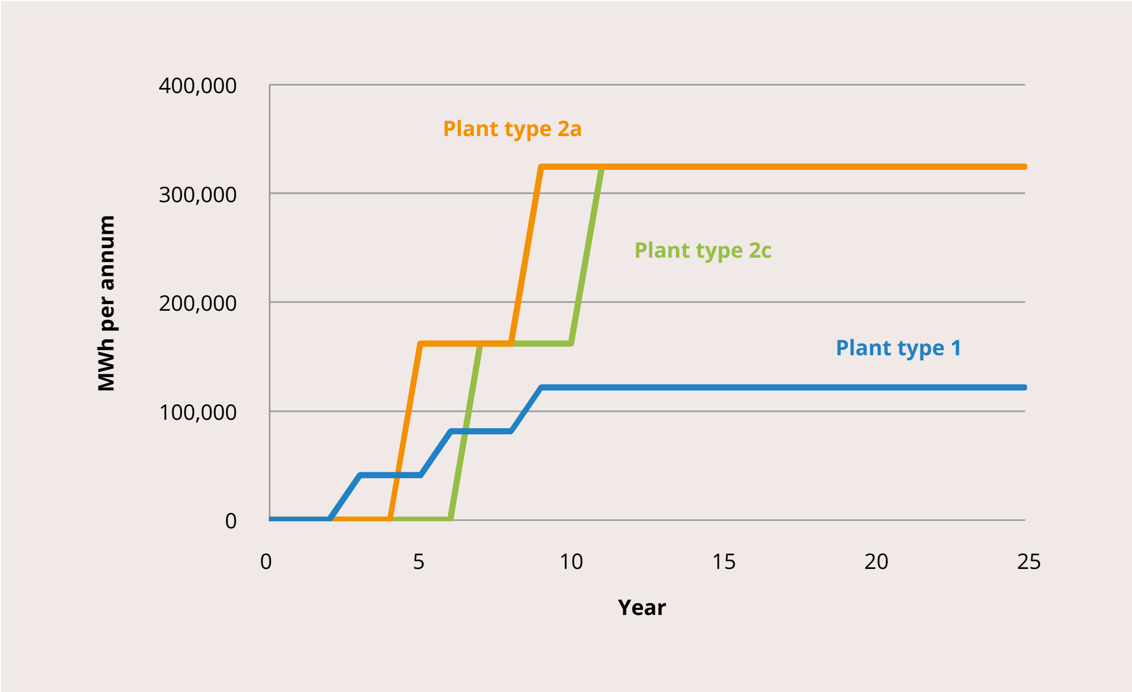
Utilisation of biomass: Bush banks

According to the analysis of the utilisation of biomass, Otjozondjupa/Namibia would not have the capacity to utilise all of the produced biomass until Year 21, after the initial round of bush control would has been completed. This opens the possibility to store it for future use in a logistic centre ("bush bank"). Thinned biomass cannot be stored indefinitely. If stockpiled in a bush bank, it is crucial that the biomass is kept very dry, otherwise it will mould and lose some favourable properties.

The study has already taken into account costs and benefits of value-adding industries in previous sections. It assumes construction on a bush bank to begin in Year 5, allowing biomass to be stored from Year 6. Construction costs would be distributed according to Ndilula, Kangombe, and

CHART 15

Electricity generation from harvested biomass



Zireva's (2016): N$ 37.8 million (USD 3.0 million) in Year 5, N$ 81.6 million (USD 6.4 million) in Year 6, and N$ 69.0 million (USD 5.4 million) in Year 7. **This results in a discounted potential cost of N$ 131.7 million (USD 10.4 million).**

Utilisation of biomass: Residual biomass

Most studies recommend some of the biomass to be left on the land, in order to return nutrients to the soil and provide some protection for new grasses coming through.

To value the benefits of the residual biomass left on the ground and not stored in bush banks, a price for mulch was used. For a cubic metre of mulch in South Africa, the price is R 130 (= N$ 130.2 (USD 10.3)). A weight-to-volume estimate of 400 kg/m^3 was used to arrive at a price of N$ 325 (USD 25.6)/tonne of residual biomass. The volume of biomass left on the ground after bush control was then multiplied by this price to estimate its value. **The discounted potential net benefit was estimated at N$ 4.6 billion (USD 0.4 billion) over the 25 year horizon.**

Multiplier effects

Employment is considered a cost in cost-benefit analysis and labour costs are included in the respective cost estimates. However, additional employment also offers benefits. The social benefits of employment can include income security and higher living standards, improvements in health and education, decreased crime and drug use, decreased family disruption, and so on.

Additional jobs and household income (labour costs) per year were estimated for five sectors: bush control operations, livestock production, hunting and game, charcoal production, and electricity production.

Additional employment and household income also have positive impacts on the wider economy. The income that these newly employed workers earn will be spend on goods and services, which creates income for the providers of these goods and services. This income can then be spend on more goods and services. This is called the multiplier effect and can be calculated based on UNDP (2010) quote Odada et. al.'s (2009) estimates for the marginal propensity to consume MPC (0.89), the

Women in charcoal production

marginal tax rate MTR (0.282), and the marginal propensity to import MPI (0.543) for Namibia. **The total discounted benefit is estimated at N$ 5.3 billion (USD 0.4 billion) over 25 years.**

Cost – benefit analysis for Otjozondjupa region

Central case analysis

In the central case, the potential net benefits of bush control accrued to an estimated **N$ 4.9 billion (USD 0.4 billion)** (2015 prices, discounted at 6%) over 25 years. Total benefits were estimated at N$ 25.1 billion (USD 2.0 billion) and include benefits for the wider economy of N$ 5.3 billion (USD 417.4 million) and costs of N$ 20.3 billion (USD 1.6 billion).

Scenario analysis

In the best case scenario, we estimate that the potential net benefit could be as high as **N$ 10.6 billion (USD 834.9 million)**. This is based on the following assumptions, which differ from the central case:

- Bush control costs are 20% lower.
- Carbon is valued at N$ 60 (USD 4.7) per tonne as in the central case.
- Groundwater recharge increases to 3% of rainfall (instead of 2%).
- Beef price increases by 20%.
- Game carrying capacity increases by 80% (instead of 50%).
- Charcoal, firewood, and animal feed price is 20% higher.
- Heavy fuel oil price is 20% higher.
- Capacity of electricity generation increases to 140 MW (instead of 95 MW).

In the worst case scenario, we estimate that the potential net benefit could be as low as **N$ 2.9 billion (USD 228.4 million).** This is based on the following assumptions, which differ from the central case:

- Bush control costs are 20% higher.
- Carbon is valued at the SCC (USD 40.1 in 2015 prices).
- Groundwater recharge increases to 1.5% of rainfall (instead of 2%).
- Beef price decreases by 20%.
- Game carrying capacity increases by 30% (instead of 50%).
- Charcoal, firewood, and animal feed price is 20% lower.
- Heavy fuel oil price is 20% lower.
- Capacity of electricity generation increases to 50 MW (instead of 95 MW).

TABLE 9

Cost/benefit analysis – central case

Variables	Cost mN$ (mUSD)	Benefit mN$ (mUSD)	Net Benefit mN$ (mUSD)
Bush thinning	12,469.9 (982.1)	0.0 (0.0)	-12,469.9 (-982.1)
Initial round	8,544.3 (673.0)	0.0 (0.0)	-8,544.3 (-673.0)
Follow ups	3,925.7 (309.2)	0.0 (0.0)	-3,925.7 (-309.2)
Ecosystem Services	2,160.2 (170.1)	2,854.9 (224.9)	694.8 (54.7)
Grazing land (cattle carrying capacity)	993.2 (78.2)	1,139.3 (89.7)	146.0 (11.5)
Water	24.1 (1.9)	430.5 (33.9)	406.4 (32.0)
Wildlife viewing	0.0 (0.0)	22.7 (1.8)	22.7 (1.8)
Hunting and game products	882.9 (69.5)	1084.9 (85.4)	202.0 (15.9)
Carbon sequestration	259.9 (20.5)	177.5 (14.0)	-82.4 (-6.5)
Soil organic carbon	64.4 (5.1)	0.0 (0.0)	-64.4 (-5.1)
Offsets	0.0 (0.0)	177.5 (14.0)	177.5 (14.0)
Cattle	195.5 (15.4)	0.0 (0.0)	-195.5 (-15.4)
Biomass utilisation	5,488.5 (432.3)	16,716.0 (1,316.6)	11,227.5 (884.3)
Charcoal	1,076.5 (84.8)	2,466.3 (194.2)	1,389.7 (109.5)
Firewood	0.0 (0.0)	633.9 (49.9)	633.9 (49.9)
Animal Feed	217.7 (17.1)	952.3 (75.0)	734.7 (57.9)
Industry power	171.4 (13.5)	672.9 (53.0)	501.5 (39.5)
Electricity	4,022.8 (316.8)	7,403.7 (583.1)	3,380.9 (266.3)
Residual biomass	0.0 (0.0)	4,587.0 (361.3)	4,587.0 (361.3)
Bush bank	131.7 (10.4)	0.0 (0.0)	-131.7 (-10.4)
Option values	0.0 (0.0)	310.0 (24.4)	310.0 (24.4)
Cattle	0.0 (0.0)	215.7 (17.0)	215.7 (17.0)
Game	0.0 (0.0)	94.3 (7.4)	94.3 (7.4)
Multiplier effects	0.0 (0.0)	5,254.0 (413.8)	5,254.0 (413.8)
Bush thinning	0.0 (0.0)	3,223.8 (253.9)	3,223.8 (253.9)
Cattle production	0.0 (0.0)	101.9 (8.0)	101.9 (8.0)
Hunting and game products	0.0 (0.0)	139.7 (11.0)	139.7 (11.0)
Charcoal	0.0 (0.0)	1,047.4 (82.5)	1,047.4 (82.5)
Electricity generation	0.0 (0.0)	741.1 (58.4)	741.1 (58.4)
TOTAL	**20,250.2 (1,594.9)**	**25,134.9 (1,979.7)**	**4,884.7 (384.7)**

Conclusion

In the central case of the national study, it was estimated that the potential net benefits of bush control would amount to N$ 48.0 billion (USD 3.8 billion) (2015 prices, discounted) over 25 years. However, under varying assumptions and scenarios, net benefits could range from N$ 24.9 billion (USD 2.0 billion) (in a scenario where the bush thinning rate was only 33%) up to N$ 111.9 billion (USD 8.8 billion) in a best case scenario. As it is expected that many of the non-quantified services would likely benefit from bush control, there might be upside risk to the underlying estimates.

The case study for the Otjozondjupa region finds that a comprehensive programme of bush control and biomass utilisation could generate an estimated potential net benefit of N$ 4.9 billion (USD 0.4 billion) over 25 years when compared with a scenario of no bush control. Total costs are estimated at N$ 20.3 billion (USD 1.6 billion) and total benefits are estimated at N$ 25.1 billion (USD 2.0 billion), which includes benefits for the wider economy of N$ 5.3 billion (USD 0.4 billion). Sensitivity and scenario analysis indicate that the net benefit could range from N$ 2.9 billion (USD 228.4 million) to N$ 10.6 billion (USD 834.9 million) (discounted).

On the regional level, it is estimated that every year 5,220 casual jobs could be generated by bush control operations and that by the end of the 25 years, more than 5,700 additional full time jobs could be created and sustained in sectors benefitting from bush control, namely cattle farming, game farming, charcoal production and electricity generation. Furthermore, the additional household income in these industries would generate wider economic benefits of around N$ 5.3 billion (USD 417.4 million) (discounted) over the 25 years.

Furthermore, business case analysis for Otjozondjupa shows that of the value addition industries, animal feed, charcoal production and electricity generation all have estimated positive industry net benefits and social net benefits. Although the social net benefit for charcoal production is estimated to be positive, the industry net benefit is estimated to be negative. More efficient technology, and therefore lower demand for biomass, would close this gap to some extend. In terms of farming, game farms are estimated to generate the largest net benefit under three different payment options for bush control, followed by mixed use farms and cattle farms.

Overall, the studies suggest that a substantial gain for Namibia's economy and social welfare can be expected from bush control, warranting support and further investigation.

Policy recommendations

National level

Recommendation 1: Implement means for bush control

This study finds that a programme of bush control could generate an estimated potential net benefit of **N$ 48.0 billion (USD 3.8 billion)** over 25 years when compared with a scenario of no bush control. In addition, bush control operations could support an estimated 10,000 jobs after the initial round. There is reason to believe that there is upside risk to these estimates, as many of the unquantified services would also be positively affected by bush control.

Recommendation 2: Improve on sustainable rangeland management

Good rangeland management practices will be crucial in preventing a vicious cycle of bush encroachment, bush control, restocking, overgrazing, and back to bush encroachment. A notable risk of bush control is that increased stocking rates (in response to increased carrying capacity) could potentially lead to overgrazing, which would in turn encourage bush encroachment.

Namibia has a policy on sustainable rangeland management (National Rangeland Management Policy and Strategy 2012) which needs to be implemented broadly alongside bush control activities.

Recommendation 3: Introduce state investments in key industries

The key ecosystem services that were estimated to increase in value due to bush control were livestock production, groundwater recharge, tourism, and utilisation of biomass through charcoal and firewood production and electricity generation. All of these services will require capital investment in order to realise their potential benefits. For example, purchase of cattle to utilise the additional carrying capacity or investment in infrastructure to accommodate greater numbers of tourists or the development of biomass power plants.

Some of these initiatives may require financial or fiscal intervention by the state. For example, it is estimated that the breakeven price for biomass-fuelled electricity generation would be N$ 2.0 (USD 0.16)/kWh. This significantly exceeds the current tariff of around N$ 1.28 (USD 0.10)/kWh, requiring a subsidy of N$ 0.72 (USD 0.06)/kWh for these plants to be feasible. However, if net national benefit is positive, the state's intervention is justified and necessary to unlock the additional benefits of securing locally-generated energy supply. It should also be noted that the breakeven price for biomass-fuelled electricity generation is less than the breakeven price estimated for the Kudu power plant of N$ 2.55 (USD 0.20), so the subsidy required would be lower. Furthermore, if bush control is subsidised, this could reduce supply costs and therefore the breakeven rate.

Recommendation 4: Pilot programme to facilitate research and data collection

Research should focus on the effects of bush control on relevant ecosystem services that are currently unquantifiable or uncertain, the environmental impacts of bush control, and on potential mitigation measures. For example, as the analysis suggests, unlocking additional groundwater volumes would be a very valuable exercise, particularly in a semi-arid to arid country as Namibia. Yet data on how groundwater recharge rates change with varying bush density is limited, as is research on the true price of water, specific to location and under scarcity (if water scarcity increases, the value of water will also increase).

There are likely significant differences in the net benefits of bush control across sectors and regions. Therefore, it is recommended that sector-specific and location-specific costs and benefits are investigated in conjunction with the Integrated Regional Land-use Planning exercises carried out by the Ministry of Land Reform as well as the Land Degradation Neutrality project led by the Ministry of Environment through its inter-ministerial Sustainable Land Management committee.

The sector-specific analysis should include a focus on the business case for each initiative to ascertain which would offer the best return. Economic multipliers and the social and economic benefits from the associated increase in employment could also be assessed for each initiative.

The location-specific analysis should be congruent with regional land use plans. Bush-encroached areas differ not only by land use, but also by bush and other species, ecosystems, soil types, population pressures, proximity to markets, and other factors. These should all be taken into account when assessing the impacts of bush control.

Otjozondjupa region

Recommendation 1: Implement means for bush control

This study finds that a comprehensive programme of bush control could generate an estimated potential net benefit of N$ 4.9 billion (USD 0.4 billion) over 25 years when compared with a scenario of no bush control. Total cost is estimated at N$ 20.3 billion (USD 1.6 billion) and total benefit is estimated at N$ 25.1 billion (USD 2.0 billion), which includes benefits for the wider economy of N$ 5.3 billion (USD 0.4 billion).

Bush control could generate a net benefit for livestock production, groundwater recharge and supply, wildlife viewing, and hunting and game products, as well as charcoal, firewood, and animal feed production, and power and electricity generation (including carbon offsets for electricity). Furthermore, wider economic (and social) benefits would arise from the additional full time jobs, roughly at more than 5700, and household income. However, it would result in net costs through bush control operations, additional emissions from livestock, and loss of soil organic carbon.

The net benefit of a comprehensive bush control programme in Otjozondjupa would be significantly positive and make a considerable contribution to Otjozondjupa and Namibia's economy and social welfare.

Recommendation 2: Involve the private and public sector

A comprehensive bush control programme deserves support from the private sector, which stands to reap returns in the long run, and the public sector, given the social, environmental and economic benefits.

Recommendation 3: Expand the Otjozondjupa research case

Further research of the Otjozondjupa case is recommended. It should focus on the effects of bush control on ecosystem services that are currently unquantifiable or uncertain, the environmental impacts of bush control, and on potential mitigation measures. The model for Otjozondjupa could also be expanded to other bush-encroached areas of Namibia. It would need to be adapted based on location specific factors, including land uses, encroacher species, other species, ecosystems, soil types, population pressures, and proximity to markets.

Although a business case for the regional assessment was analysed, further gaps and limitations can be addressed through related work. This includes further natural resource economics work undertaken by the Ministry of Environment and Tourism (MET), with the Resource Mobilisation Project (ResMob), the developing of Integrated Regional Land-Use Plans by the Ministry of Land Reform (MLR) and LDN assessments championed by the Sustainable Land Management Committee.

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