Bush Control Manual

MINISTRY OF AGRICULTURE, WATER AND FORESTRY

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Beyond Bush
De-bushing Advisory Service

Imprint

COMMISSIONED BY:
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Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
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Appendices: Courtesy of National Botanical Research Institute (NBRI)

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PRINTED BY: John Meinert Printing

ISBN: 978-99945-85-83-0

FIRST PUBLISHED 2017

The Bush Control Manual serves as a practical information tool for farmers dealing with bush encroachment and is part of a series of production manuals in rangeland and livestock management produced by the Farmers' Support Project (FSP) in 2009, under the auspices of the Namibia Agricultural Union (NAU) and Namibia National Farmers Union (NNFU).

OTHER PRODUCTION MANUALS IN THE SERIES:
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Foreword

The challenge of bush encroachment has accelerated in recent decades. In 2004 De Klerk estimated that more than 30 million hectares of Namibia's prime land is affected. In a Strategic Environmental Assessment conducted in 2016, this figure was estimated to have increased to 45 million hectares. The impacts of bush encroachment are well known, though not always well understood. The declined carrying capacity of rangelands mostly in commercial agricultural land in central and eastern regions as well as localised parts of communal areas in the north is generally known. This is further stimulated by the inherent characteristics of infertile soils and rainfall variability in Namibia.

As a national advisory service provider, the De-bushing Advisory Service aims to serve the farming community, land users and industry at large by addressing knowledge and information needs of those interested in bush control.

The prime benefit of bush control is to restore the carrying capacity of rangelands. In conjunction with sustainable rangeland management, competition of bush with grasses can be reduced significantly. Soil moisture and nutrients allow grasses to grow lusciously where previously growth had been stunted by dense bush. This so-called "grass explosion" can lead to productive and healthier rangelands.

Game farmers can restore views of landscapes thereby boosting game viewing tourism. Further ecological benefits include improved recharge of underground water, restored native wildlife habitats, and enriched biodiversity.

In this manual, causes and impacts of bush encroachment are discussed. A closer look is being taken at encroacher bush species and their properties, methods of bush control with strengths and limitations as well as aftercare methods. Written and reviewed by rangeland experts, care will be taken to continuously develop this topic enhancing your understanding of and ability to manage bush encroachment effectively.

Bush control is a highly individualised topic. Every case is unique, having specific characteristics and requiring a specialised approach. Objectives as a farmer, current condition of the land and farming enterprise further determine the most sensible and effective solutions.

We hope this manual will be helpful in tackling the bush encroachment challenge on your farm.

Progress Kashandula
General Manager: De-bushing Advisory Service

Acknowledgements

This manual was prepared by Dr. Axel Rothauge (AgriConsult Namibia) on behalf of the Support to De-bushing Project, a bilateral cooperation between the Namibian and German Governments, implemented by the Ministry of Agriculture, Water and Forestry (MAWF) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The content is based on a range of studies, including by M.J. de Wet, DECOSA, SAIEA, and Cheetah Conservation Fund. The manual's development was further enhanced by contributions from an Advisory Committee consisting of MAWF-Directorate of Forestry, Jonas Mwhiikinghi, MAWF-Directorate of Agricultural Research and Development, Elina Shekupe Nakanyala; Farmers' Support Project (now Agri Advisory Services Division within the Agricultural Bank of Namibia), Erastus Ngaruka and Günther Roeber who provided valuable input to key sections. Colin Lindeque of the Namibia Biomass Industry Group (N-BiG) provided important input on the costs of bush control. We are very thankful to all those who contributed images. We apologise for any infringement of copyright to those whom we were unable to acknowledge. Finally, this manual has benefited from a wide range of input received from industry, governmental, and non-governmental experts.

List of abbreviations

BE	Bush Equivalent of 1.5 m height
CCF	Cheetah Conservation Fund
CO_2	Carbon Dioxide
DAS	De-bushing Advisory Service
DEA	Directorate of Environmental Affairs
DECOSA	Development Consultants for Southern Africa
DoF	Directorate of Forestry
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Ha	Hectare
NAU	Namibia Agricultural Union
N-BiG	Namibia Biomass Industry Group
NCA	Namibia Charcoal Association
NECFU	Namibia Emerging Commercial Farmers' Union
NNFU	Namibia National Farmers Union
MAWF	Ministry of Agriculture, Water and Forestry
m	Metre
mm	Millimetre
MSDS	Material Safety Data Sheet
SME's	Small and Medium Enterprises
SAIEA	Southern African Institute for Environmental Assessment

Introduction

Managing Land Successfully

As a farmer, you are also a land manager. Bush encroachment is an enormous and complex challenge. There is no "quick fix" or a "one size fits all" solution. Your management needs to be comprehensive, strategic and long-term.

Know your land
Farmers have superior knowledge of their livestock and they need to extend that knowledge to their land and vegetation. What is the state of bush encroachment on my farm? Is it in a transitional state or am I facing full-fledged bush encroachment? Which are the encroaching species? The first chapter of this manual looks at causes and impacts of encroachment. It also introduces a set of tools that helps to monitor the land and explains essential legal requirements. At the end of the manual you will find an overview of encroacher bush species in → Appendix A and protected species in → Appendix B.

Create value
Encroacher bush can be valuable. Producers are encouraged to harvest encroacher wood and add value to it to help offset the costs of bush control. The current economic utilisation of encroacher bush in Namibia focuses mainly on firewood for local communities and charcoal for exports. Buyers of wood chips for energy production are emerging. Some products require larger investments; others do not but may still lead to considerable value addition. The brochure "Adding Value to Namibian Encroacher Bush" gives an overview of various products. It is available online at www.dasnamibia.org.

PRODUCTS MADE FROM ENCROACHER BUSH

Firewood

The demand for firewood in Namibia is expected to increase. Prices range from N$ 1,700 per tonne in Kavango Region to N$ 3,000 per tonne in Katutura suburb of Windhoek (based on informal retail prices).

- Variety of species suitable
- Very low investment required
- Labour intensive
- No additional production inputs (e.g. water, electricity) required

Charcoal

Namibian charcoal is mainly exported to South Africa and Europe. The market for barbecue charcoal is under-supplied and the gap between demand and supply is estimated to increase further.

- Variety of species suitable for high quality barbecue charcoal
- Relatively low investment required
- Simple technologies provided by local SMEs
- No additional inputs (e.g. water, electricity) required

Compressed firewood

Compressed firewood is another product produced at an economic scale from encroacher bush. It is known as "biomass briquettes" or "wood logs" and the Namibian product is known as "bushbloks". The product is made through a process of grinding the biomass and subsequently compacting it. Compressed firewood is mainly used for heating and leisure activities such as barbecuing. Due to their high density, briquettes have longer burning times than conventional firewood.

Wood chips

The main off-takers of wood chips in Namibia are Ohorongo Cement near Otavi which uses chips from encroacher bush to fire industrial combustion chambers and Ohlthaver & List (O&L) at the breweries in Windhoek.

- Harvesting is typically done by dedicated harvesting companies and farmers pay a fee per hectare
- Mobile harvesters and chippers convert the bush to wood chips

Animal feed

Animal feed refers to fodder made from encroacher bush as the main ingredient supplements. This is an ideal value chain for livestock and game farmers. It provides affordable fodder during emergency situation, such as droughts, but also as supplementary feed throughout the year. A number of Namibian farmers are already producing bush feed and a new study has tested various diets. In many cases bush feed has proven to be the only viable option for farmers especially during the dry periods.

Consult the following document for further information on potential products:
DECOSA (2015). Value added end-use opportunities from encroacher bush in Namibia.
http://www.dasnamibia.org/download/brochures/Brochure_Debushing_Value-Chains-2015.pdf

Choose your bush control method

Chapter two gives an overview of bush control methods. You can contact us, the De-bushing Advisory Service (DAS), for more technical advice on appropriate harvesting techniques and equipment. We can refer you to service providers and equipment suppliers. Please find more information on the website www.dasnamibia.org such as brochures on harvesting and quantifying bush as well as on financing options.

Avoid re-encroachment

Chapter three is dedicated to aftercare practices and sustainable rangeland management. Namibia's National Rangeland Management Policy and Strategy (2012) promotes the implementation of principles, rather than rules and regulations. You can also find it in the download section at www.dasnamibia.org.

It is advised that everyone considering bush control and harvesting consults an expert first (e.g. DAS, N-BiG).

Bush Encroachment in Namibia

1

Bush encroachment is an increase in woody plants that results in the loss of grazing capacity, causing considerable productivity losses for both commercial (freehold) and communal (non-freehold) farmers in Namibia. The expansion of certain opportunistic indigenous shrubs in both density and area happens in response to various global and local drivers. Of these, favourable rainfall, disruption of the grass:bush balance of a savanna and the suppression of hot fires are probably the most important. There are a few positive effects as well, such as increased soil stability and fertility. Bush is an integral and valuable component of a savanna that provides invaluable services to the soil and animals. Encroacher bush should therefore never be eradicated, but merely thinned to a more natural (acceptable) density.

Main encroacher tree and shrub species

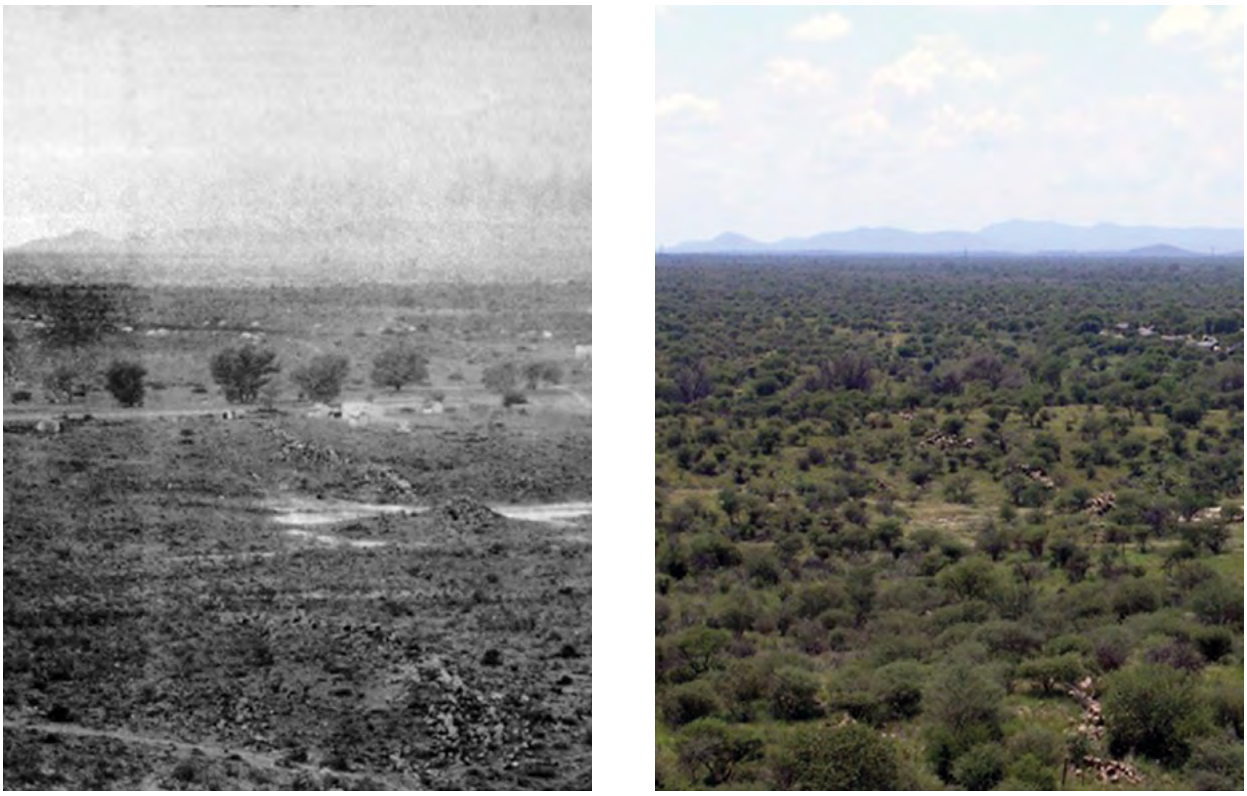
- *Acacia luederitzii (Vachellia luederitzii)*
- *Acacia mellifera (Senegalia mellifera)*
- *Acacia reficiens (Vachellia reficiens)*
- *Colophospermum mopane*
- *Dichrostachys cinerea*
- *Rhigozum trichotomum*
- *Terminalia prunioides*
- *Terminalia sericea*

Other species of lesser importance as encroachers

- *Acacia erubescens (Senegalia erubescens)*
- *Acacia fleckii (Senegalia fleckii)*
- *Acacia nilotica (Vachellia nilotica)*

For a full description and characteristics of the species see →Appendix A

Encroachment is not a steady process but one that happens occasionally or sporadically. It sometimes starts in specific, small patches which expand gradually over several decades. Often, the process occurs unobtrusively and virtually unnoticed so that land users do not realise what is going on until the whole landscape is covered in bush.



An open savanna overlooking Gross Barmen in 1876 (left); The same view in 2009 (right).

Bush encroachment is primarily a process of thickening of bush species which have been observed in a certain area before. However, encroachment can also include an expansion of species that have not occured commonly in that area before. For example, it appears that *Dichrostachys cinerea* is expanding into drier areas southwards while *Rhigozum trichotomum* is expanding into moister areas northwards.

Vegetation balance

In a savanna, dry woodland and Nama-Karoo shrubland the balance between grass and woody plants is fairly stable. Bush encroachment disrupts this balance. The herbaceous, grassy component is degraded in quality (species diversity and nutritive value declines) and quantity (grass yield declines and is less persistent) and encroached by woody plants.

Growth rate of bushes

At a certain density, the growth rate of a bush population slows or stops due to intense intra-species competition between individuals and they remain locked in a sexually immature state. Once external factors cause thinning, individuals grow again. A thicket may therefore remain stable at a certain level of development for very long periods of time. Only once individuals are spaced widely enough to access sufficient resources will they become sexually mature and produce seed. The denser a stand of immature encroacher bush, the more stable it is.

Root system of bushes

Encroacher bush competes with its own species and other plants because of its extensive root system. A grown bush has a lateral root system that may extend seven times further from the stem than the bush's height. The shallow lateral roots of bush utilise shallow ground moisture more effectively than grasses. The deep taproots of woody plants access deep ground water and keep them alive during dry phases that kill more shallow-rooted plants such as grasses. The root system of woody plants thus gives them a competitive advantage over grasses.

1.1 Causes of Bush Encroachment

There are global and local causes of bush encroachment. Climate change, disruption of the balance between grass and bush in the savanna due to non-adaptive grazing and the suppression of fires are probably the most important ones.

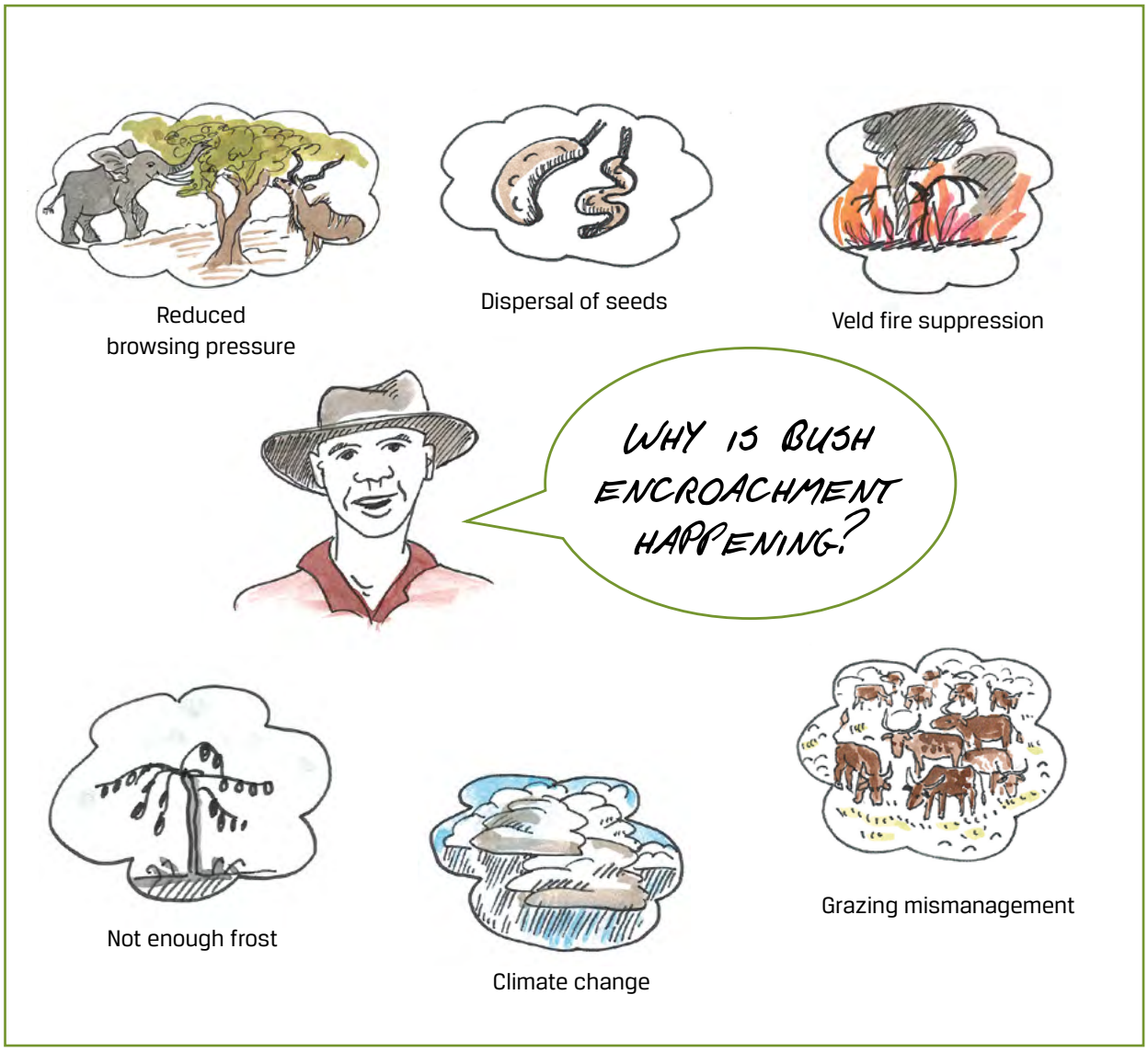


Illustration 1: **Causes of bush encroachment**

1.1.1 Unsustainable grazing management

Inappropriate grazing weakens the roots of grasses. They no longer take up water and nutrients effectively and are unable to suppress emerging bushes. The water and nutrients left in the soil are then taken up by bushes, fuelling their growth at the expense of grass growth and recovery. This can also happen when periods of drought, which reduce the grassy layer, are followed by periods of high rainfall – this creates very favourable conditions for woody plants to establish themselves in large numbers.

In present-day Namibia, the main forces that weaken a savanna grass sward are

- overstocking the land (too many animals), and
- keeping animals on the land for too long (continuous or semi-continuous grazing) in the rainy season.

Desirable perennial grasses can not adequately recover from grazing in the active growth season, they weaken and allow woody plants to start dominating.

1.1.2 Veld fire suppression

Fire stops the development of woody seedlings into mature plants. High-intensity fires, so called "hot" fires, kill the seedlings and saplings of woody species. Farmers often suppress these fires. This way, they involuntarily speed up the rate of bush encroachment.

Over-frequent burning (as in the Western Zambezi) also facilitates bush encroachment. If a fire burns "cold" because it does not have a lot of fuel to burn, it is not fierce enough to kill woody saplings, but still weakens the grass sward.

1.1.3 Climate change

The change in the world's climate is a global driver of bush encroachment that operates in the background and is easily overridden by local drivers of bush encroachment. Global warming is caused by rising atmospheric concentration of CO_2, which in turn "fertilises" woody plants and allows encroacher bush to grow faster than grasses in Namibia. However, it takes a series of above-average rainfall seasons to initiate bush encroachment from seed. The emerging bush seedling soon sinks a long taproot that accesses deeper soil moisture than relatively shallow-rooted grasses and gives it an adaptive advantage over grasses during dry spells.

1.1.4 Frost

Severe frost can kill woody seedlings. The taller a sapling grows, the less susceptible it becomes to frost. Frost typically occurs in patches in low-lying areas, resulting in a mosaic of living and dead bush.

1.1.5 Reduced browsing pressure

The displacement of browsers, such as kudu, by cattle or other grazing livestock puts extra pressure on the grassy component and relieves pressure on the woody plants. Mega-browsers such as elephants and black rhino stunt the development of woody saplings. Similarly, heavy browsing pressure by large populations of ungulate browsers (e.g. kudu, giraffe, impala), domestic goats, lagomorphs (e.g. hares, rabbits) and rodents can prevent the transition of a weakened savanna towards full-scale bush encroachment. Over-browsing kills or suppresses the development of woody saplings, delays maturity in sub-adults and may reduce seed production.

1.1.6 Seed availability

A weakened grass sward, a series of wet years and the absence of forces that kill woody seedlings leads to the sudden mass establishment of woody encroacher species with soft-coated seeds if these are present in the seed bank. *Acacia mellifera, A. reficiens, A. luederitzii, A. erubescens* and other thorny species with soft-coated seeds form typical "same size, same age" mono-stands, reflecting episodic establishment, whereas encroacher species with hard-coated seeds (e.g. *Dichrostachys cinerea*) are thought to establish much more regularly.

A SAVANNA CONTAINS THE SEEDS FOR ITS OWN ENCROACHMENT:

- Soft-coated seeds are dispersed mostly by the overland flow of rainwater following heavy rainfall.
- Hard-coated seeds (from e.g. *A. erioloba, A. hebeclada*) are well protected and long-lived. The hard seed coat prevents germination, so it has to be damaged (scarred) first by fire, passage through the digestive tract of animals or attempted predation by seed-eating animals such as weevils and rodents before germination is possible.

1.2 Impacts of Bush Encroachment

Bush encroachment has a range of negative impacts. At the same time, the bush leaves and pods can provide animals with valuable nutrients – which is one of the positive impacts of the increase in woody plants.

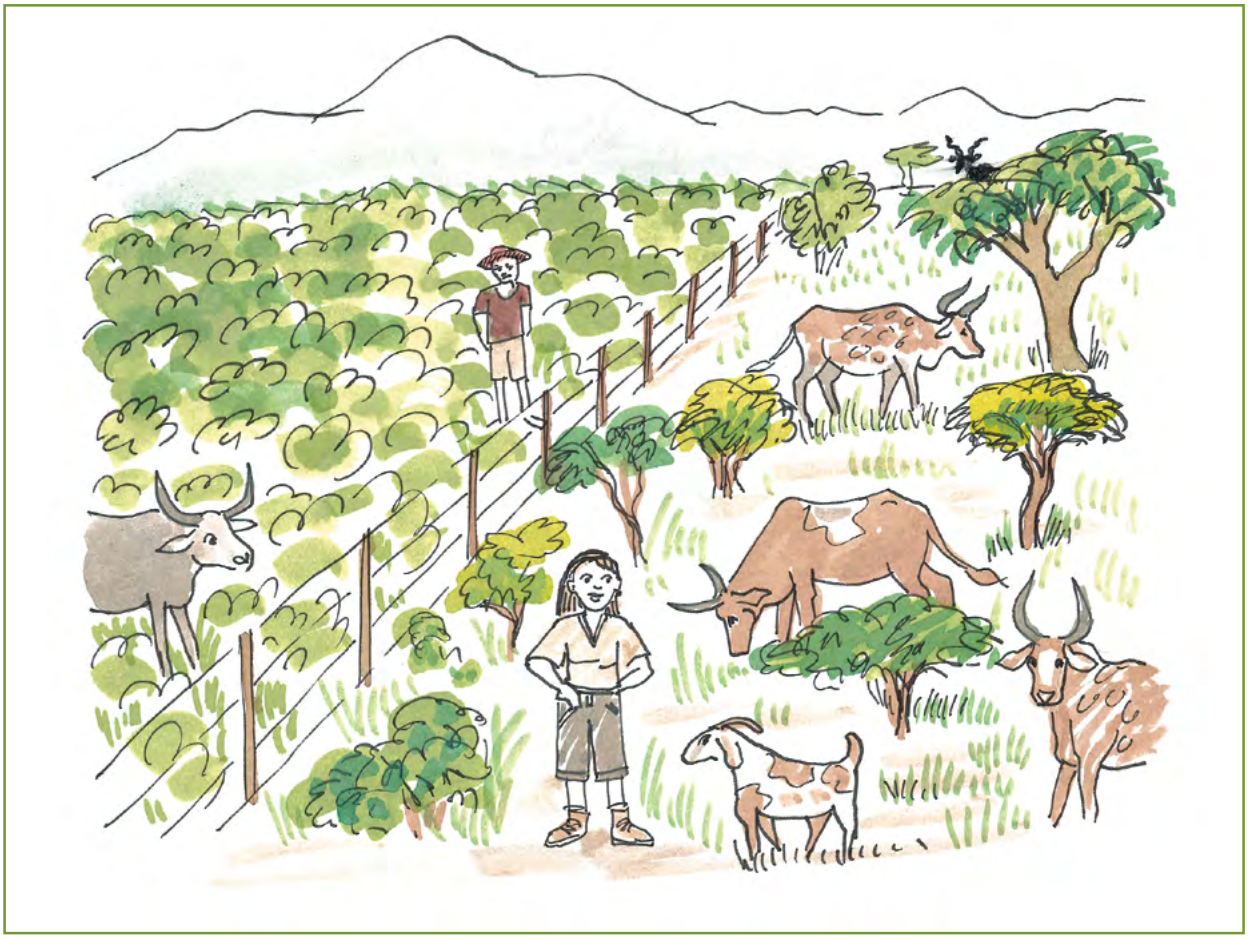


Illustration 2: **Effects of bush encroached land versus bush thinned land**

1.2.1 Negative impacts

- The grass-based carrying capacity of farmland is reduced. In extreme cases to as little as one-tenth of its original grazing potential.
- A bush-encroached landscape is less biodiverse than the original savanna state. As the grasses suffer, so do the grazing animals. Even browsing animals find it difficult to penetrate and utilise a thorny thicket.
- The landscape becomes dull and monotonous. This has implications for tourism as tourists are commonly drawn to Namibia's wide, open landscapes.
- Poor visibility due to bush encroachment has negative implications for farming security as it obscures livestock and game poachers from view.
- Preliminary results of a hydrological study in Namibia show that bush encroachment has a negative impact on groundwater recharge – not only reducing the moisture available in the soil but also reducing the probability of groundwater recharge by approximately one-third.

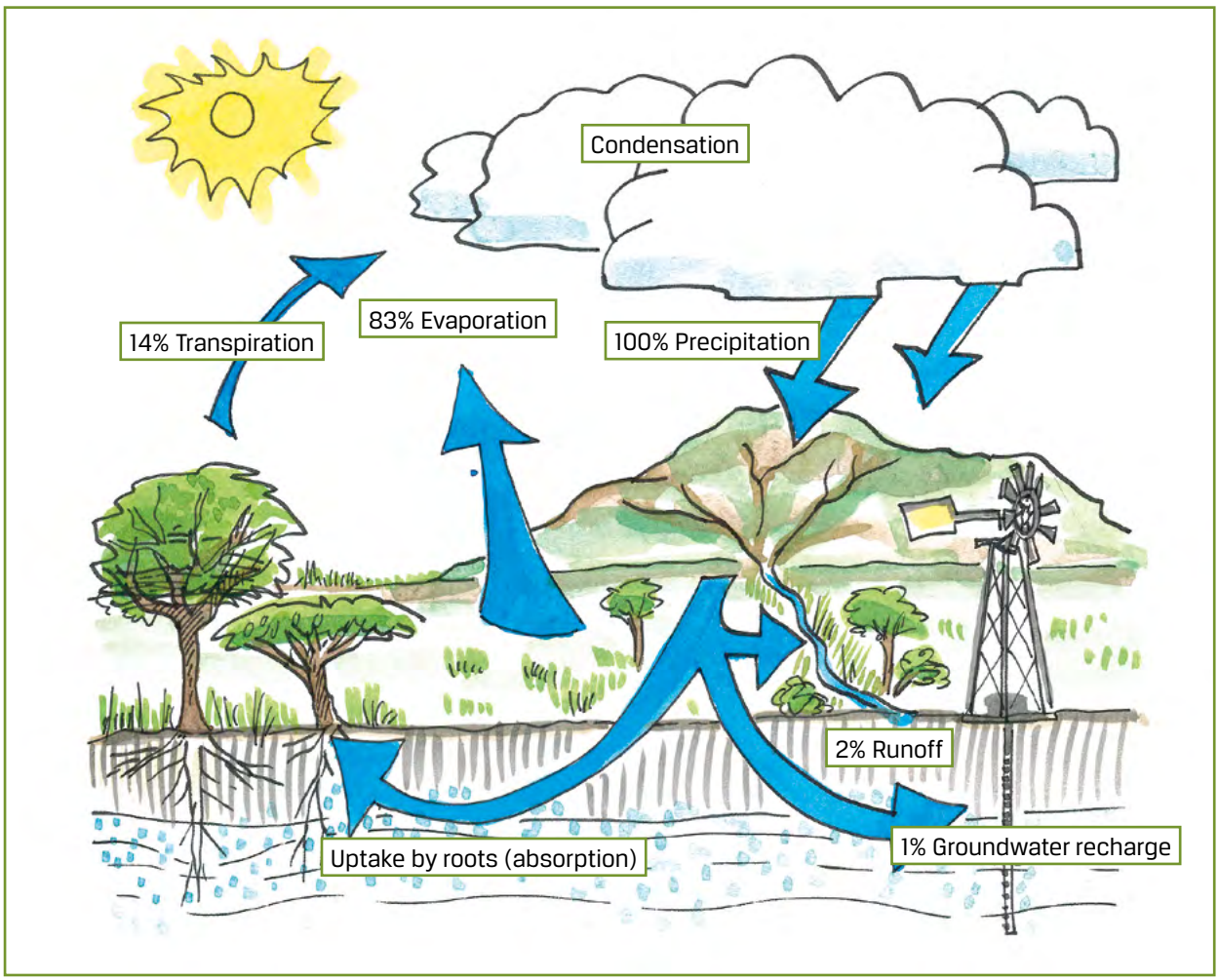


Illustration 3: **Water Cycle** (Source: Van Vuuren 2008)

1.2.2 Positive impacts

- Ecologically, the soil under a bush thicket is well protected against erosion. The strong root network of bush binds the soil and the bush canopy shades it.
- Most encroacher bush species in Namibia are leguminous and deciduous. This means it enriches the soil continuously with nitrogen and seasonally with leaf debris. The best proof of this ecological service is the "grass explosion" that takes place after bush control. The fertilisation effect of bush is most valuable on leached, sandy (dystrophic) soils.
- Woody plants and their pods provide foraging animals with valuable nutrients. Even grazing livestock such as cattle and sheep browse occasionally, especially during the annual dry season when grasses have withered. Compared to grass, bush leaves provide significantly more dietary protein, minerals and vitamins but less digestible energy. Some may contain anti-nutrients such as tannins, or poisons such as alkaloids. Completely clearing bush would have a negative impact on the nutrition of wild and domestic animals.
- The most exciting aspect of bush control is the inherent economic value of its wood. Bush encroachment results in lots of wood that can be used to make value-added products, create employment and grow the agricultural and processing sectors of the national economy. For example, encroacher bush should be the main target of the country's awakening biomass industry. Wood of encroacher bush also has a huge role to play as a renewable energy resource.

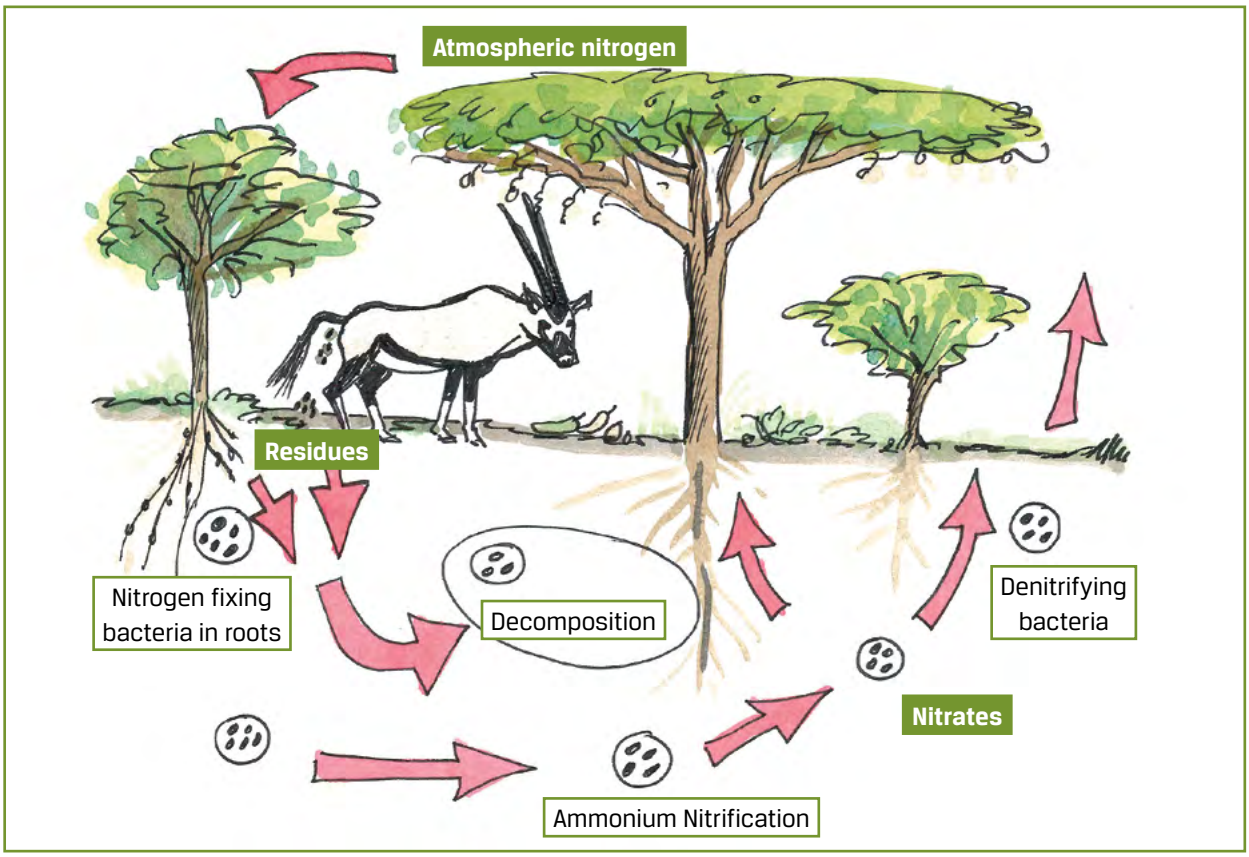


Illustration 4: **Nitrogen-fixing Cycle**

1.3 Monitoring Bush Encroachment

The best way to observe if bush encroachment is taking place in a weakened grass sward is to monitor certain patches of the savanna regularly, especially after good rainfall seasons, to see if woody seedlings are emerging.

1.3.1 Recognising the transitional state

If woody plants are emerging, the transition will advance to full-scale bush encroachment if not controlled. However, transition may take decades so there is a long window of opportunity to alert land managers to intervene. The best way to recognise the transitional state of a savanna is to know its climax and pioneer grass species. Many pioneer species have a short life; they are annuals. Climax grasses are longer-living grass species that are usually palatable and nutritious. When climax grasses are replaced by pioneer grasses, competition with bush weakens and bush encroachment is supported.

When a savanna is in the transitional state of bush seedling establishment, the survival of woody seedlings and saplings depends on a number of forces:

- If the grass cover is open and low, frost may kill woody seedlings during severe winters.
- Heavy browsing pressure may stunt or kill woody saplings.
- If the grass cover is dense and lush after two or three successive years of good rainfall even in pioneer veld, a hot fire may kill off woody seedlings and saplings and prevent full-scale bush encroachment.
- Measures that increase the abundance and vigour of perennial grasses arrest the further development of bush saplings and may eventually lead to their death by increased inter-species competition or fire.

1.3.2 How to calculate bush density on your farm

Bush density is conventionally expressed in bush equivalents per hectare. A "bush equivalent" (BE) is a standardised, 1.5 metre high bush. A density of encroacher bushes (BE per hectare) that exceeds twice the long-term average rainfall (in millimetres per year) represents bush encroachment. Commercial farmers often experience bush densities exceeding 2,000 – 3,000 BE/hectare which seriously degrades rangeland. At 5,000 to 6,000 BE/ha, thorn bush becomes impenetrable and density is difficult to measure physically. It is estimated that densities of 24,000 BE/ha occur in Namibia.

However, in areas that are naturally more woody (e.g. north-eastern Namibia) or with sandy, dystrophic soil (e.g. eastern Namibia), bush encroachment is only problematic once bush density (in BE/ha) exceeds three times the long-term average rainfall (in mm/year).

A "bush equivalent" (BE) is a standardised, 1.5 m high bush.
Bush density can be measured on any small sample area that is representative of the larger area, the farm or rangeland generally. Plot measurements are then extrapolated to one hectare (10,000 m^2).

1. Select any small area (50 m^2 for example) that is representative of the bigger area.
2. Count the number of encroacher bush plants growing on the plot and measure the height of each one.
3. Record bush height in classes of 1.5 m (the size of one bush equivalent), e.g. 0 – 1.5 m, 1.5 – 3.0 m, 3.0 – 4.5 m, 4.5 – 6.0 m etc.
4. Multiply the number of bush in each height class with their height, e.g. 7 bushes × 1.5 m = 10.5 m, 4 bushes × 3.0 m = 12.0 m, 2 bushes × 4.5 m = 9.0 m and 2 bushes × 6.0 m = 12.0 m
5. Add all height class totals together and divide by 1.5 m, e.g. 43.5 m ÷ 1.5 = 29.
6. This is the number of bush equivalents on the plot, i.e. 29 BE/50 m^2.
7. Extrapolate this sub-total to 10,000 m^2 (one hectare) = 5,800 BE/ha.

Compare the measured bush density to the long-term average annual rainfall of the plot or farm. For example:

- If the farm is in the Mariental district where the long-term average annual rainfall is 250 mm, the recommended bush density is only 500 BE/ha. The land user can remove the excess of 5,300 BE/ha.
- If the plot is near Grootfontein with a long-term average annual rainfall of 650 mm, the recommended bush density is 1,300 BE/ha. The land user can remove the excess of 4,500 BE/ha.

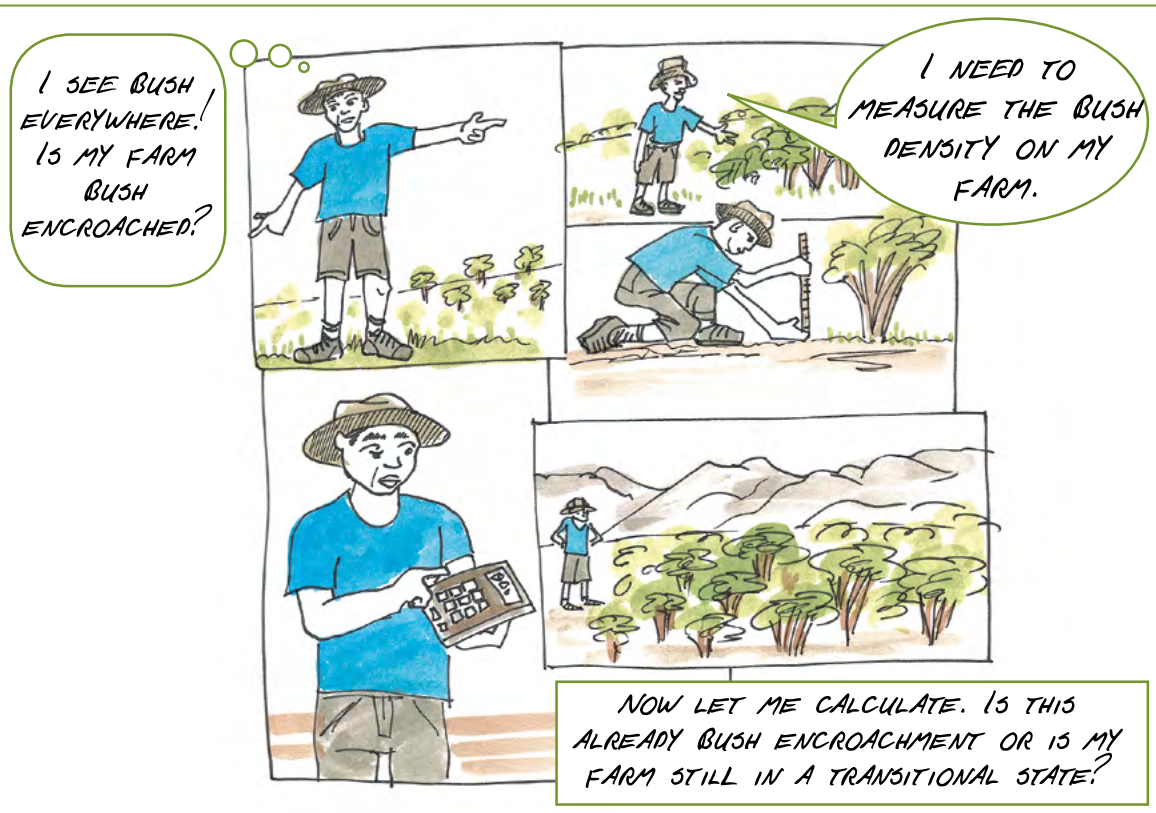


Illustration 5: **Measuring bush density**

1.4 Approaches to Bush Control

The conventional system of comparing bush density to average rainfall offers a rigid approach to bush control. The adaptive approach, on the other hand, is guided by a more intuitive understanding of nature. The adaptive approach to bush control is ecologically much more preferable than the rigid approach.

1.4.1 A rigid approach to bush control

What is, ultimately, the best density of woody plants on the land after bush control? To answer this question, a generalised, rigid system of ultimate bush densities has been developed.

Optimum density in a rigid system

- It is commonly assumed that the optimum density of all woody plants (in BE/ha) is twice the long-term average annual rainfall (in mm).
- In the moister north-eastern regions of Namibia, the optimum woody density should be increased to three times the long-term average annual rainfall to accommodate the natural woodiness of the area.
- Similarly, on coarse Kalahari sand, the optimum woody density should also be increased to three times the long-term average annual rainfall to allow for sufficient nutrient enrichment of the sandy soil by woody plants.

How to apply the system

- First assess the existing density of all woody plants targeted for bush control.
- If the total density of woody plants exceeds the optimum or targeted density, some woody plants have to be removed selectively, starting with the encroaching species and smallest individuals.

Leave on the land

Do not remove:

- Any protected woody species. Some protected woody species may become encroaching under certain conditions and specialist inputs may be required to decide on the thinning of protected woody species under these conditions.
- Any woody individuals with a stem diameter exceeding 18 cm at breast height. Such large individuals are protected by the Forest Act no. 12 of 2001 as they are ecologically valuable.
- A significant number of woody plants from within 100 metres of a river course to protect this potentially flooded area from soil erosion. The Forest Act no. 12 of 2001 prohibits the cutting, removing or destroying of living trees, bushes or shrubs within 100 metres of a river bank.
- Encroaching woody species completely. Larger specimen should be left intact in the interest of biodiversity and patchiness.

1.4.2 An adaptive approach to bush control

With this approach, you "read" the lay of the land and thin accordingly. This approach is not guided by hard-and-fast rules but by an intuitive understanding of local ecology.

Original versus encroaching generation

In most cases of bush encroachment, especially by the most important species (acacias, *Dichrostachys cinerea*), the difference in physical appearance between the "original" growth

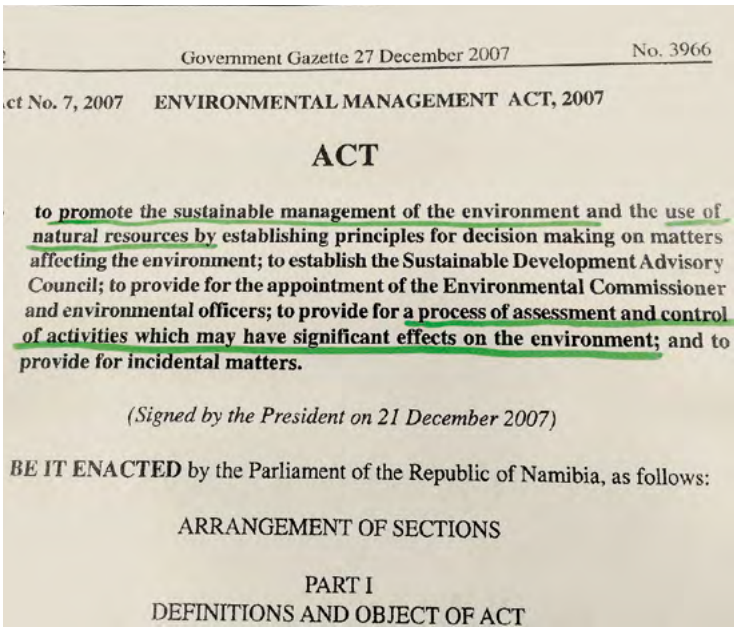
of woody plants which thrived on the land prior to rangeland degradation and the "encroacher" growth which grew because of rangeland degradation is clearly visible and remarkably distinct.

- The "original" growth consists mostly of larger, thicker, more mature plants of a variety of species, as well as the young ones growing up here-and-there to replace dying old trees. The "original" growth should be left standing.
- The "encroacher" growth is characterised by thin and multi-stemmed, same-size, same-age bush of the same species or a small variety of known encroacher species. They look distinctly different to the "original" growth and should be removed nearly totally. A few immature specimens should be left on the land because they could be part of the generational chain of the "originals" and are not true members of the "encroachers".

Further information on how to quantify bush density can be found in:

- De Klerk (2004). Bush encroachment in Namibia. Prepared for the Ministry of Environment and Tourism, Windhoek.
- Smit et al (2015). Detailed assessment of biomass resource and potential yield in a selected bush encroached area of Namibia. http://www.dasnamibia.org/download/brochures/Brochure_Debushing_Resource-Assessment-2015.pdf

1.5 Legal Requirements of Bush Control



Government Gazette 27 December 2007 No. 3966

ct No. 7, 2007 ENVIRONMENTAL MANAGEMENT ACT, 2007

ACT

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

(Signed by the President on 21 December 2007)

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

ARRANGEMENT OF SECTIONS

PART I
DEFINITIONS AND OBJECT OF ACT

Environmental and forestry legal requirements.

Environmental protection is enshrined in the Namibian Constitution and sustainable development has formed a cornerstone of Vision 2030. Thus, the government is committed to actively promote and maintain environmental welfare by formulating and implementing policies that can realise sustainable development. These fundamental principles are supported by various international, regional and national legal instruments. Ultimately, the responsibility toward environmental protection and sustainable development is obligatory for everyone and every institution active within Namibia. On the next page are key regulatory requirements that individuals and business entities involved in bush control and biomass utilisation should comply with.

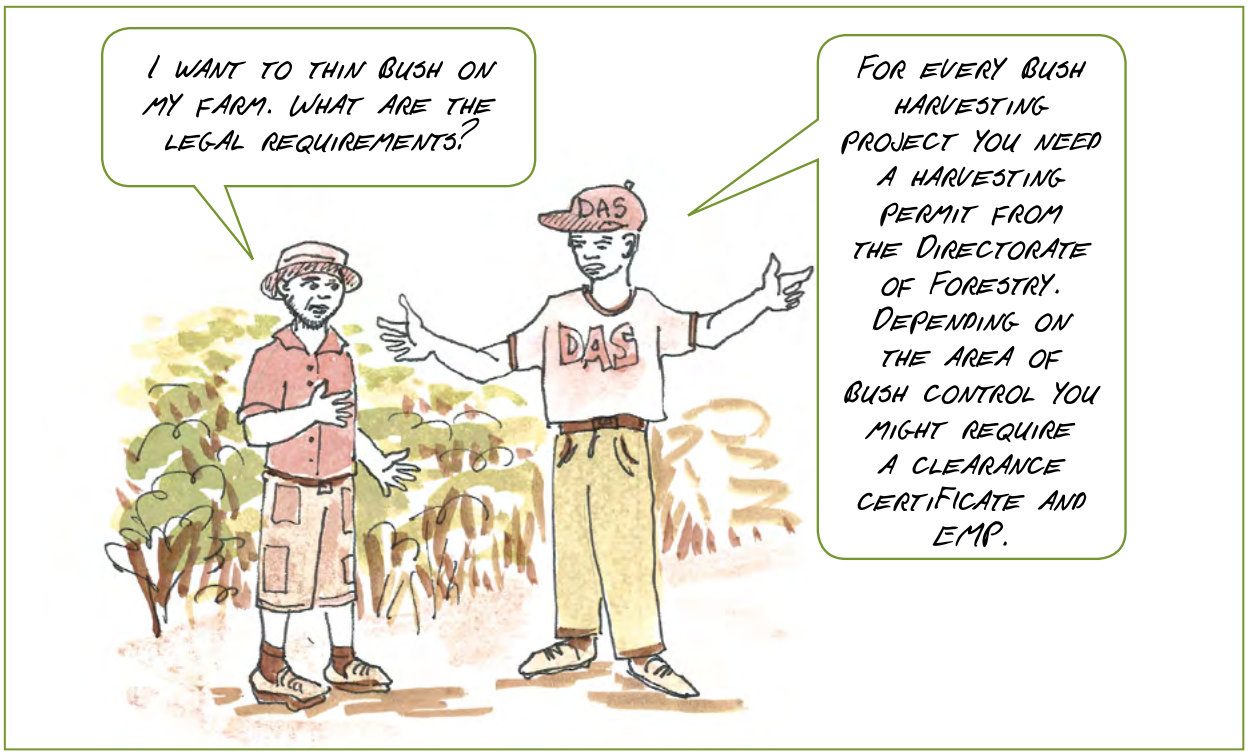


Illustration 6: **Regulatory processes for bush thinning**

Forestry Permits

All harvesting of trees and wood in Namibia is governed by the Forest Act of 2001 and its 2015 Regulations. This Act is administered by the Directorate of Forestry in the Ministry of Agriculture, Water and Forestry.

Harvesting Permit

A Harvesting Permit is required for any tree cutting and/or harvesting of wood for commercial purposes. The permit is issued by a Licensing Officer. It stipulates conditions of the harvesting. Inspection of an area to be harvested is done before the permit is issued and when an application for renewal is made every 3 months. The cost for commercial purposes is N$60, for communal purposes it is N$20 valid for 7 days and for own use it is N$ 10 valid for 3 days.

Transport Permit

A Transport Permit is required to convey any wood or wood products (e.g. droppers, planks, charcoal, and firewood). It is obtainable from any Forestry Office, and is valid for 7 days at a cost of N$ 20 for commercial purposes and 3 days for own use at a cost of N$10.

Export Permit

An Export Permit is required to send any wood or wood products outside Namibia. It is obtainable from any Forestry Office and is valid for 7 days for commercial value added products costing N$20 per tonne up to 10 tonnes. An additional fee of N$5 per tonne is required beyond 10 tonnes.

Marketing Permit

A Marketing Permit is required to enable the producer to sell his/her products to any other party. The permit is valid for 3 months in commercial areas at a cost of N$60 while in communal areas the permit is valid for 1 month only.

Environmental Clearance Certificate

The Environmental Management Act no. 7 of 2007 and its 2012 Regulations is administered by the Environmental Commissioner in the Department of Environmental Affairs (DEA) in the Ministry of Environment and Tourism (MET). Normally, to obtain an Environmental Clearance Certificate, an Environmental Impact Assessment (EIA) has to be completed together with an Environmental Management Plan (EMP).

- An EIA is an assessment of the environmental damage that a project might cause. An EIA is usually carried out by an independent environmental practitioner. The EIA report is evaluated by the DEA, and if the Environmental Commissioner is satisfied that the negative impacts are minimised, an Environmental Clearance Certificate is issued.
- The EMP provides advice on how the negative impacts can be avoided or reduced.

For bush harvesting the application process has been simplified to reduce costs and time delays. There are three categories of harvesting:

1. **No Environmental Clearance Necessary:** All wood harvesting activities in areas less than 150 hectares per year require only a Harvesting Permit from the Directorate of Forestry.
2. **Environmental Clearance based on generic EMP:** Medium-sized bush harvesting operations covering an area between 150 – 5,000 hectares require a Harvesting Permit and an Environmental Clearance Certificate. The area to be thinned should be less than 5,000 hectares altogether in one vicinity. The EIA can be customised from a generic Environmental Management Plan. You can find such a plan online (www.dasnamibia.org, Resources/downloads/Policies, "Forestry and Environmental Authorisations Process for Bush Harvesting Projects"). The level of consultations with interested and affected parties for this category should focus on neighbouring farms. This is on the assumption that the potential impact is foreseen to be localised. Neighbours' consent should be submitted to DEA with the application. If a farmer harvests individual areas that are less than 5,000 ha, but they contribute to a larger project that covers an area greater than 5,000 ha, then the activities fall into category 3 (full EIA).
3. **Environmental Clearance based on full EIA and EMP:** Large bush harvesting operations covering an area greater than 5,000 hectares are likely to have extensive, complex and/or long-term environmental impacts. They require a full EIA and include a thorough EMP. The EIA must cover all the specific details of the source areas. Individual farms that contribute harvested wood to a large project will all be bound by the conditions described in the EMP.

Labour Act

The Labour Act no. 11 of 2007 concerns mainly the fair and safe treatment of workers involved in bush control. Regulations relating to the Health and Safety of Employees at Work (of 1997) need to be adhered to in terms of the employment conditions of all employees.

Aerial Application of Arboricides

Aerial spraying has been widely used in Namibia, with the justification by farmers that it is an "emergency" treatment and more cost effective when bush is so dense that other methods of clearing are simply not practical. However, aerial spraying is now illegal as outlined in the Forestry Act Regulations, 2015 (Sections 22, 23/Regulation 12). Application of arboricides by hand is still allowed as this is more selective.

All wood harvesting activities require a Harvesting Permit from the Directorate of Forestry in the Ministry of Agriculture, Water and Forestry.

2 Bush Control Methods

Which method of bush control works best? There is no universal answer to this question. It depends on farmers' objectives, the encroacher species they face, the landscape as well as the investments they are prepared to make. This chapter discusses the common methods of bush control. Every method has its benefits and disadvantages. The emphasis is on practical application of each method, how to implement it correctly, how to maximise the desired impact on encroacher bush while minimising collateral damage and unintended consequences. Guidance is also provided on the ultimate bush density aimed for after bush control. It is recommended to seek expert advice prior to embarking on a bush control exercise.

Main Principles of Bush Control

- Concentrate bush control on species and individuals that are obviously part of encroacher growth and leave the others alone.
- Leave a mix of trees and bushes on the land: The veld should have a variety of tree species (including some of the encroacher species) of different sizes. They should be spaced in a way that there are some open patches and some dense patches. This provides a variety of habitats for animals and imitates the heterogeneity (patchiness) of natural landscapes.
- Thin bush in a phased approach: Avoid to "shock" the land by an abrupt change from dense bush to open veld.
- Protected plants should not be harvested. Exceptions can be made under supervision of Forestry officials in cases of high densities.
- If arboricides are being used, foliar (leaf spray) and stem-applied arboricides are recommended. Pellets should not be used, as they tend to get washed along the surface by rain and end up in non-target areas.
- Dry river beds tend to carry more and larger trees. Forestry regulations state that trees should not be thinned within 100 metres of a river course. Thinning is required in densely encroached river margins, but one should leave a higher density of trees than on the adjacent habitat. It is especially important to leave large trees along a river course. The exception to this is *Prosopis*, an exotic species that invades river beds, and should be eradicated completely.
- Training of the work force is necessary before harvesting starts. Workers need to know which trees to target and which to avoid. Work teams need to be managed so that any excessive harvesting or killing of the wrong species is noticed and corrected.

Illustration 7: **Planning for bush thinning**

COST OVERVIEW OF BUSH CONTROL

Method	Equipment	Cost Estimate (NAD)	Further Reading
Manual	Axes, pangas and spade	1,000 – 3,000/ha	1. De Wet (2015): Harvesting Namibian Encroacher Bush 2. DECOSA (2016): Concept for Sustainable Labour-based De-bushing in Namibia 3. Cheetah Conservation Fund: https://cheetah.org/
Semi-mechanised	Conventional bush cutter, heavy duty bush cutter and chain saw	1,500 – 2,000/ha	
Mechanical	Heavy mechanised cutting machine with clippers, small bulldozer with circular saw, heavy bulldozer and bush roller	750 – 4,000/ha	
Chemical: manual application of arboricides	Pump sprayers and by hand	500 – 2,600/ha	NAMAGRI: http://namagri.com/products-services/bush-encroachment/
Planned fire	Axe, spade, shovels, hoe, picks (manual) and mechanised machinery such as graders and tractors	About 100/ha	Forest Act (2001) and Regulations (2015), Refer to Guidelines on constructing fire cutlines.

2.1 Manual and Semi-mechanised Bush Control

Manual control of bush is achieved by hand labour and using hand tools only. Semi-mechanised control involves the use of hand-held power tools that are not self-propelled.

2.1.1 Manual bush control

Manual bush control is most suited for small-scale operations where cost and time are less important than selectivity of control.

How it works

At its most elementary level, manual control is a person with the appropriate hand tools taking out individual bushes. Such manual control is highly selective if the worker has been well trained. However, chopped stems that remain behind can coppice if they are young enough and are not treated chemically, burnt or dug out.

Manual felling of bush using a hand tool.

How to apply

With a spade and a bush pick or axe, a worker can dig out a large *Acacia mellifera (Senegalia mellifera)* bush in about 15 minutes by cutting its roots off 10-20 cm under the ground. The remaining rootstock has no "eyes" (active auxiliary buds) left and does not coppice. The speed of operations depends on the size of the bush and the sandiness of the soil. A good worker can control all large bushes on one hectare in 1-2 weeks while smaller bushes can be controlled in half the time.

In soft and/or wet soil, it is possible to pull out smaller bushes, exactly the size that is usually the problem in bush-encroached rangeland, roots-and-all using a leveraged gripper like the "Exit Tree Popper". Soil disturbance is negligible, output and costs are low and selectivity high. Thorny fines should be spread on the land to counter soil erosion or protect grasses.

Costs

The costs below reflect only the felling process and not the further processing of the wood for value addition.

Ha/person/day	0.05 – 0.2
Estimate costs NAD/ha	1,000 – 3,000

The disadvantage of this type of manual control is that it is very labour intensive and time consuming. To speed up manual bush control, many land users prefer to simply chop off the bush. The output increases tremendously and reduces unit costs.

2.1.2 Semi-mechanised bush control

Semi-mechanised methods are becoming more popular as they make the back-breaking work of manual bush control much easier, faster and cheaper by shrinking unit cost due to improved productivity.

How it works

In an effort to retain the advantages of manual bush control (ease of implementation, high selectivity, low investment costs) but address its disadvantages (low output, hard work, medium to high operational costs), land users are increasingly outfitting their workers with hand-held power tools. With many of these methods a cut stump remains behind that may coppice unless killed off chemically or burnt, and may obstruct farm traffic.

Hand-operated saw-mobiles are useful against thorny encroacher bush as they keep the operator out of harm's way.

How to apply

Various patents of mobile, hand-propelled remote saws powered by small, mounted engines (so-called "saw-mobiles" or trolley saws) can be pushed underneath a bush to keep the operator away from thorns. These hand-propelled mobile saws come with horizontal or vertical saw blades for ease of use under all conditions and can often be made at home. Hand-held power tools are inappropriate for thorny bushes as the saw operator is too exposed to the thorns of the bush.

One specific farmer had nearly only emerging bush saplings on his land; his rangeland was in the transitional stage from grassy to woody. Seeing his woody plants were nearly all thin-stemmed, soft-wooded individuals, he razed them with a Weed eater-like appliance with a solid blade rather than a string. Obviously, such a weak tool will only be effective against this particular group of very young woody plants.

All semi-mechanised methods of bush control expose the machine operator to extreme danger. It is essential that machine operators receive thorough training in the safe operation of their machines. Operators should also be equipped with adequate personal protective equipment which should include ear muffins.

Costs

Productivity increases 3 to 5 times compared to the manual method. The table below indicates only the felling process and not the further processing of the wood for value addition.

Ha/day	3
Estimate costs NAD/ha	1,500 – 2,000

The rate of bush control using these methods is very slow, and mainly done to produce charcoal, firewood and products such as poles.

2.2 Mechanical Bush Control

The mechanical control of encroacher bush is achieved with self-propelled machines equipped with various appliances that vary in size from small, wheeled tractors (e.g. the "Bosvark") to heavy, track-mounted bulldozers designed to move earth (e.g. a "D6"). Selectivity of control and costs vary with the size of the machine. Small machines can generally extract encroacher bush much more selectively than larger machines, although some large extractors also handle every bush individually and are thus highly selective. Selectivity also depends on the level of alertness and skill of the machine operator.

Costs

Operating costs are linked to machine size, operator, maintenance etc. Most heavy equipment has to be operated by specialists and skilled operators. This tends to add to cost. Generally, mechanised bush control is just as expensive as chemical control or more so. Operating costs increase with the fuel price and have recently come down noticeably thanks to the decline in commodity prices.

Depending on bush density, workers can control bush in an area of 0.5 – to 4 ha with a mechanised cutting machine. In some instances, a large portion of the felling costs can be offset by the subsequent value addition to the wood by selling the biomass.

Ha/day	0.5 – 4
Estimate costs NAD/ha	750 – 4,000

How to it works

2.2.1 Bulldozers

A bulldozer can clear large areas (up to 5-8 ha/day) depending on bush density and the degree of selectivity. At 4 m wide, a bulldozer blade is not inherently selective but the huge machines are surprisingly manoeuvrable and can be steered around large non-target woody plants by a skilled and alert operator. Its blade is lifted slightly above ground level and the bush is then either flattened and broken off or, most often, pulled out of the soil, roots-and-all.

With this method, the topsoil is disturbed considerably. The tracks too cause considerable soil disturbance, noticeably more than by wheeled machines. When clearing, the ground is often left bare. Bare ground can easily lead to desertification. Clearing is suitable for the preparation of crop fields and is not recommended for bush control on grazing land.

An example of the soil disturbance common to blade-equipped heavy machines employed against encroacher bush.

2.2.2 Heavy Saws, Clippers and Pullers

Wheel- and track-mounted heavy machines can be outfitted with saws, clippers and leveraged scoops to control encroacher bush. Since these tools are all designed to treat woody plants one-by-one, they are inherently selective.

They are comparable to bulldozers in cost as they often use a bulldozer base on which the specialised tool is mounted. However, "mini-heavies" have been designed which are easier to manoeuver and can reach difficult areas.

The wheeled "Bosvark" is purpose-built to control encroacher bush. It is fitted with a saw blade and protects the operator with a strong grid against falling tree parts. It is highly selective and can treat 3-5 ha/day depending on bush density and the desired selectivity. In contrast to track-mounted machines, its wheels and relatively small size cause very little soil disturbance. It is the ideal "mini-heavy" machine to control encroacher bush but its purchase price places it outside the realm of many land users.

A track-mounted behemoth with a highly flexible saw blade that can swing from vertical to horizontal has some of the Bosvark's advantages (selective and manoeuvrable) and most of the bulldozer's disadvantages (expensive to purchase and operate, tracks cause major soil disturbance). Therefore it is not a successful compromise and has not yet become popular in Namibia.

A recent development in heavy bush control machinery is a track-mounted tree clipper with several graspers and one basal cutting blade mounted on a long, front-end loader-type flexible arm. These machines are extremely expensive in purchase and operations and are only used in high-value applications of wood (e.g. making chips for industrial furnaces).
They cut woody plants at ground level and stack them in heaps and windrows, ready for collection by specialised machinery such as grinders which process the whole bush into high-value products such as wood chips. Tree clippers are extremely selective as every woody plant has to be grasped and clipped individually, which limits output to 2-4 ha/day depending on bush density.
Operators have to be highly skilled (not re-trained farm workers) as the control of the grasping arm is extremely complicated. While very effective, their specialist nature will probably limit their application on Namibian farms.

A much cheaper version of the tree clipper's long, front-end loader-type flexible arm is fitted with a scoop and can be mounted on the power-take-off of a tractor, to excavate rooted plants by pulling them up. It is the mechanised model of the tree popper discussed earlier. Even though relatively cheap and very selective, it is not in use much in Namibia, probably because its output (ha/hr) is low and it does not extract bush well from hard, non-sandy soil.

2.2.3 Heavy Rollers

Mechanised heavy rollers break bush off at the base (at ground level) due to their weight. The heavier, the more effective they are. Initial home-built models were a bit too light for the job at hand but were soon scaled up to heavyweight industrial machines with rollers of 4-6 tonnes in weight. The earlier models pulled the roller and thus subjected the tractor to a lot of wear and tear and the driver to whiplashing branches. The up-scaled, industrial model pushes the roller in front of the tractor, which requires relatively more power than rolling but is easier on man and machine and reduces compaction of the soil as the roller "floats" over a layer of flattened bush.

In dense thickets, the heavyweight roller never touches the ground as it drives over a blanket of rolled encroacher bush, requiring adapted tyres with special chains to prevent tyre blow-out. Early models were largely home-built and cheap (about N$250/ha) but have been phased out. The up-scaled, industrial model can be rented from N$750/ha upwards. It can treat 5-15 ha per day depending on bush density and is thus very efficient.

The stumps remaining in the ground can coppice if the bush was thin-stemmed and young and would have to be treated with chemicals to ensure they die off. Since the rollers are not as wide as a bulldozer blade, selectivity of which bush to roll is comparatively better. Heavy rollers work extremely well on sandy soil but stones and rocks can reduce efficiency and access.

An early, largely home-built roller that proved too light to break large encroacher bush but is effective against smaller bush. The fact that the roller is pulled behind the tractor is a mechanical disadvantage.

A heavy industrial roller pushed ahead of the tractor is highly efficient and relatively selective.

Presentation of wood after heavy rolling. Note the minimal soil disturbance and stumps that may have to be treated chemically to die off.

A rolled thicket is an impressive sight: the rolled bush has been flattened and, unlike most other bush control methods, does not present a visual obstruction. The horizon is visible again, a sight long un-seen in many Namibian landscapes. Young, flexible bushes stand up again after rolling, leaving the treated veld with adequate live woody cover even if the driver treated the whole area. The thick wood of flattened bushes is presented nicely on the ground, ready for harvesting and value addition.

Even if the thick wood is removed in a subsequent operation for value addition, a lot of fragmented thorny fines will remain on the land, resulting from branches broken by the heavy roller and protect the land against the elements like a wooden blanket. Impact of the heavy tractor and roller on the soil is minimal as they "float" on a layer of rolled wood that protects the topsoil from impact.

For least environmental harm, any mechanised thinning should create minimal disturbance to the soil, and should be able to select appropriate trees to be controlled, and avoid others that are desired. Further information on felling, chipping and grinding equipment, please refer to the brochure by De Wet (2015) Compendium of harvesting technologies for encroacher bush in Namibia. Accessible at www.dasnamibia.org.

2.3 Chemical Bush Control

Of all the bush control methods used in Namibia, it appears that chemical control is in most widespread use. A survey in 2014 amongst Namibia's commercial farmers found that two-thirds of those who control encroacher bush do so by chemical means, using arboricides. In general, controlling encroacher bush by chemical means is an effective method. However, incorrect use can cause more damage than good.

How it works

Chemicals used to kill woody plants such as encroacher bush are called "arboricides". They are a specific type of herbicide (chemicals that kill plants) designed specifically to kill woody plants (although they kill herbaceous plants too).

The most common application of arboricides are

- to the soil,
- to the leaves, and
- to the cut stem of woody plants.

ABOUT ARBORICIDES

An arboricide typically consists of one or more active ingredients that kill the plant and "adjuvants" that are added for other purposes than killing plants. Adjuvants could be soaps, stabilisers, colorants and similar chemicals and are not chemically inert. The most commonly-used arboricides appear to be non-toxic to larger mammals.

Arboricides kill all plants but are specifically effective against woody plants. Arboricides thus have to be applied selectively to kill targeted plants only. Arboricides are not supposed to have any residual effect, i.e. they should not kill woody plants for many years after application. The exception is when they are absorbed into the groundwater, where they can remain effective, it appears, for many years and can be swept off-site to kill non-target trees. The skeletons of bushes and trees remain standing for an unusually long period of time as arboricides kill off the micro-organisms needed for decay and decomposition of wood.

Limitations

Once treated correctly, chemically killed bush does not grow back. However, arboricides do not kill bush seeds. Bush seeds in the soil germinate rapidly when rainfall is favourable and establish within 2-3 years, potentially re-colonising the landscape soon after chemical bush control. Also, many small bushes below grass-emergent height survive chemical control because they are easily overlooked and not treated. When the large bush is killed, the immature, small bushes rapidly grow up. As with other bush control methods, it is thus imperative to apply aftercare to treated areas to prevent their re-encroachment within a decade. This creates a practical problem to farmers whose exhausted financial means often do not allow the degree of aftercare that is required. It is thus common that farmers do not apply the required aftercare and then struggle with re-encroachment soon. Generally, Namibian farmers use arboricides too readily when there are non-chemical methods of bush control available that could be just as effective but less environmentally damaging.

Costs

Compared to manual and semi-mechanised methods of bush control, arboricide application is expensive. The amount of arboricide that has to be applied depends very much on bush density, species and soil properties. The cost of chemical application can be around N$ 500/ha if the bush densities are low or smaller bushes on sandy soils are treated. It can be as high as N$ 2,600/ha if densely encroached land on clay soils is treated. For *Dichrostachys cinerea*, the concentration of arboricides is often doubled, which increases the cost of treatment considerably.

Estimate arboricide costs NAD/ha	500 – 2,600

How to use arboricides safely

Arboricide use has implications for human and environmental health, therefore it is essential to use them correctly.

Appropriate personal protective equipment, including water-resistant rubber gloves, a mouth mask and goggles protects the worker during foliar spraying of bushes, directing the spray downwards to avoid spray drifting into the face of the operator.

Follow instructions

It is imperative with all chemicals to always read and follow the instructions of the manufacturer on the label and instruction leaflet. They spell out the basic handling, storage and safety requirements. Store safely. Avoid spills and accidental leakage.

Caution

The Material Safety Data Sheet (MSDS) of every active ingredient and every arboricide should be provided with the product or can be downloaded from the internet before use. The MSDS provides complete information on an arboricide. While reliable, the problem with MSDS information is that chemical safety is usually determined by short-term experiments that do not consider long-term effects. In the Dordabis area for example, large riverine trees are dying off 15 years after upstream farms were treated intensively with arboricides from the air. This illustrates the extremely long residual effect of some of these substances in an arid environment.

Ensure safety of people

Personal protective equipment that prevents the chemicals from coming into contact with skin, eyes, mouth and nostrils is a basic requirement.

Mix carefully

Mix in a place that is either far away from non-target vegetation or in the midst of a thicket to be treated anyway. Generally, it is safer not to mix different liquid arboricides unless it is stated expressly in the manufacturer's instructions that they are compatible. If they have to be mixed, it is always safer to add the smaller volume to the bigger volume.

Do not pollute water sources

All arboricides are soluble in water and can be distributed to distant sites where they can cause unintended damage. Never wash spilled residues down a sewer system or clean and wash arboricide equipment near open bodies of water or boreholes. Rather soak up the spill and discard absorptive material on a recognised waste dump site or burn it.

Wash equipment in buckets and discard the wash water in the midst of a bush thicket, or use it again the next day to dilute a concentrate solution. Be especially careful when washing vehicles that transported arboricides, applicators or equipment. Do not park the vehicle on a lawn or wash it under a favourite shade tree. This vegetation may be killed by traces of arboricide in the wash water.

Dispose responsibly

Dispose of empty arboricide containers by rinsing them several times with water. Add rinse water to the next spray mix. Puncture and flatten the arboricide container so it is unusable. Follow the manufacturer's instructions on safe use and disposal meticulously.

2.3.1 Soil-applied arboricides

Soil-applied arboricides are the most popular method of bush control in Namibia. They must be applied to the soil under bush canopies, near the stem. Once it rains, the active ingredient is leached out of the arboricide, enters the shallow soil moisture and is absorbed by bush roots. When the arboricide circulates through the bush it inhibits photosynthesis in the leaves which turn yellow and fall off. Soil-applied arboricides are best suited for first control of dense and monotypic infestations of encroacher bush.

Products

- Soil-applied arboricides used most often in Namibia contain the active ingredients "bromacil" or "tebuthiuron".
- These arboricides come by many different trade names such as "Hyvar", "Bushwhacker", "Brush-free" (containing bromacil), "Spike", "Graslan", "Grazer", "Limpopo", "Molopo" or "Reclaim" (containing tebuthiuron) or combinations thereof.
- They all have the concentration of active ingredients printed on the label, e.g. "tebuthiuron content 25 per cent". This means that 25 per cent of the arboricide consists of the active ingredient tebuthiuron and while 75 per cent consists of other chemicals that have other functions than killing plants.

How to apply

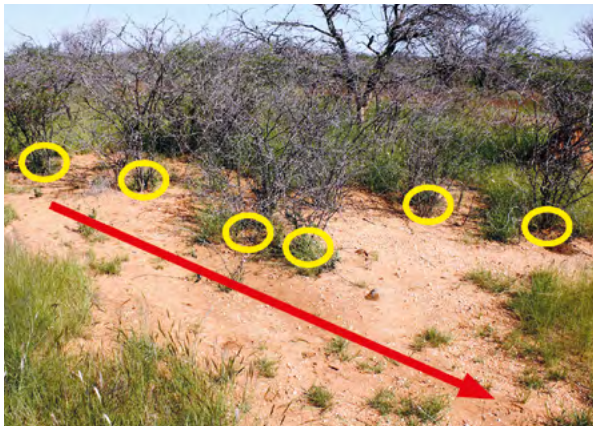
Soil-applied arboricides come in three main formats.

- They can be pelleted, in which case the recommended dose of pellets, e.g. one gram for every 1 m of bush height, must be strewn under the canopy of the targeted bush. Pelleted arboricides are often brightly coloured so it is easier to see where and how much was been applied.
- They come as a powder that must be mixed with water to form a solution, or
- as a soluble concentrate which must be diluted with water to the correct concentration. The diluted solution is then squirted with a hand-held applicator onto the soil below the bush or onto its stem at the recommended dose. Solutions to be sprayed onto the ground are often coloured bright pink, again making application and control easier.

A worker can treat 5-10 ha of land with pellets daily, or 3-10 ha if applying a solution. Soil-applied arboricides can be applied at any time of the year, even in the dry season, but they only become active once it rains. They should best be applied in the first half of the rainy season. However, if the first rains storms are violent, pellets get washed sideways quite easily. Pelleted arboricides should thus only be used on flat terrain where runoff water movement is not severe.

Although soil-applied arboricides have been tested to be non-toxic to humans, applicators should still protect themselves by wearing rubber gloves and long-sleeved shirts and boots to prevent contact with the skin. Applicators should follow the safety precautions on the instruction leaflet strictly.

Bright blue arboricide pellets that are easily visible, are applied under the canopy of a small bush and around its stems. However, the illustrated dose is too large for such a small bush. The danger exists that excess arboricide will be absorbed by roots of other woody plants growing in the vicinity and kill non-targeted individuals.



The encroacher *Dichrostachys cinerea* in the middle of the picture was targeted by arboricide pellets applied to the base of each bush (yellow ovals). However, pellets were overdosed and killed the tree right-of-centre, which was not targeted. The first rains of the season swept some pellets away from their area of application and they sterilised the soil, preventing grass growth (red arrow from back-left to front-right of picture).

Limitations and dangers

Soil-applied arboricides are formulated to bind to soil particles to prevent them being leached deeper into soil. This means that some active ingredient will remain behind in the soil for some time, causing a residual killing effect. Incidents are known from Namibian farms where soil-applied arboricides still kill non-target trees decades after the last application, indicating that the residual effect may be much longer than assumed in quality control tests and stated in MSDS.

It is best to use soil-applied arboricides only when faced with a very homogenous stand of encroacher bush. They are not suited for selective control in a botanically diverse setting or to control isolated bush patches and should never be used near open water or river courses. Do not apply nearer than 50 m to protected trees lest these are killed involuntarily.

2.3.2 Foliar- and Stem-applied arboricides

Foliar-applied arboricides are applied to the leaves of plants. They are used to clear small areas selectively, e.g. along fences and power lines or patches of bush on the rangeland. Foliar-applied arboricides are not distributed in the soil or by groundwater. This makes foliar-applied arboricides much better to use in confined spaces, in bio-diverse settings or near protected trees.

Stem-applied arboricides are used in combination with mechanical or manual control methods. Since it is applied in very small amounts to very small areas, it is one of the most selective and safe methods of chemical bush control, but as it is always part of a larger felling operation, this does not necessarily make the whole operation ecologically sensible.

Products

Foliar-applied arboricides come by various trade names such as "Plenum", "Browser", "Tordon" and "Access" (contain picloram), "Garlon", "Confront", "Ranger", "Triclon" and "Viroaxe" (contain triclopyr) and "Tordon Super" (contains both picloram and triclopyr).

These products are all concentrated solutions that have to be diluted with water to the recommended concentration of the spray mix. The concentration of active ingredients is printed on the label, e.g. picloram content 33 per cent. This means that 33 per cent of the arboricide consists of the active ingredient picloram while 67 per cent consists are other chemicals that have other functions than killing plants, e.g. they are soaps that dissolve the waxy layer of leaves, aiding penetration of the active ingredient into the leaf.

How to apply

Foliar-applied arboricides must be sprayed onto the leaves of the targeted bush to kill it, wetting at least 75 per cent of its leaves. It is absorbed through leaf stomata and circulates through the plant. Its active ingredients, most commonly "picloram" and "triclopyr" kill the plant by stimulating it to grow excessively, thus exhausting its carbohydrate reserves. It can only be applied in summer when woody plants are actively growing and have green leaves. Preferably, the targeted bush should be shorter than the human applicator so the spraying action is downwards and away from the body.

A dye mixed into the arboricide spray makes it easier to see where and how much spray was applied. The blue coloration remains visible for some weeks, enabling supervisors to inspect work efficiency long after the work was completed.

Limitations and dangers

Foliar-applied arboricides are not suited for the control of vast areas of bush thickets. The requirement that the human applicator has to be able to move freely around the targeted bush to spray it from all sides makes its use in a thicket highly impractical. Also, applicators tend to over-spray a bush until

it drips because they cannot see the amount applied. It is thus useful to mix the arboricide with a dye that makes it visible. The most common dye for this purpose is a blue dye available under various trade names such as "Eco-Dye Blue" and "Vulcano Blue".

No withdrawal period is specified for most foliar-applied arboricides and they are not toxic to larger mammals. It appears safe to allow livestock animals to utilise recently treated plants, although it is always best to delay grazing for some time after treatment.

Foliar-applied arboricides are also absorbed through the stem of a woody plant. This makes them suitable to treat cut stems to kill the rootstock of felled bush, i.e. to be used as stem-applied arboricides. If bushes are felled manually or mechanically and the rootstock is not killed, it can re-grow (coppice) soon, leading to rapid re-encroachment. Treating cut stems with an arboricide prevents this.

➜ Arboricides should not be over-used as they potentially damage the environment. They have to be applied selectively and not over-dosed. Do not use near water and remember to protect the applicant.

2.4 Biological Bush Control

Biological bush control methods are often ineffective against the ultra-high bush densities observed in Namibia and although preferred, are more appropriately used as aftercare rather than first-line control.

Biological bush control happens when encroacher bush is killed by natural factors.
The most important biological control agents of bush in Namibia are:

- Fire, often managed and
- Fungal attack, which happens without human interference.
- Drought, frost and water-logging are other biological control agents that can kill encroacher bushes, especially while immature.
- Intense browsing pressure by animals used to be an effective control mechanism when bush density was less, but is no longer effective against ultra-dense bush.

Of all bush control mechanisms, biological control requires the least human intervention. Despite seeming to involve whole landscapes covering thousands of hectares, biological control agents never affect all areas equally and do not homogenise the landscape as do mechanical and chemical control methods. A fire for example always burns some areas more intensely than others and some not at all, creating a mosaic effect of different habitats.

2.4.1 Wood Fungi

How it works

Fungi like *Phoma glomerata* have several hosts (including some crop plants) and badly spoil structural plant fibres, causing natural die-off. In *Acacia mellifera*, they attack the red heartwood so that it rots away and leaves a hollow core in the middle of the tree stem. Fungi are moisture-dependent and only active during the rains. The spores of *Phoma* are found all over

the Namibian environment and can survive long inhospitable periods, awakening when conditions are conducive.

As fungi are only active in wet conditions, heartwood rot takes place while the mature bush appears to be flourishing, but it is actually damaged mortally. The next environmental stressor, e.g. a drought, kills the bush.

Limitations
Unfortunately, no-one has yet managed to collect and distribute spores to control encroacher bush by causing artificial die-off. We are dependent on nature and as a result, this natural control mechanism is currently not a planable/dependable part of our bush control toolbox.

2.4.2 Browsing Pressure

How it works
In a pristine savanna, browsing animals are a critical driver of bush control. Small animals (e.g. weevils, mice and birds) damage seeds of woody plants while larger animals consume the bark (e.g. porcupine) and leaves (e.g. browsing ungulate game animals), thus limiting the growth and distribution of woody plants and preventing landscape-level encroachment.

Limitations
On most livestock farms, browsing pressure is very light as it is exerted mainly by grazing domestic livestock. Once bush thickets have established, browsing appears ineffective for bush control. Trials at Omatjenne Research Station with domestic goats have shown that the browsing intensity required to significantly damage established bush thickets is ultra-high so that all the more palatable fodder bush species are completely wiped out before control of encroacher bush is achieved, i.e. the outcome is not worth the damage.

Only mega-browsers like elephant could possibly damage an established bush thicket. However, it is not possible to farm with wild elephants roaming the grazing area. Browsing pressure by goats is best used as an aftercare method to prevent re-encroachment from seed or coppice.

Wild browsing animals such as impalas feed on bush and thereby contribute to natural biological control.

2.5 Planned Fire

Planned fires seldom control existing dense mature bush but rather kill woody seedlings and saplings while they are still fire-tender. The best use of planned fires is for aftercare.

How it works

In pristine ecosystems, naturally ignited fire in the late dry season is most important to maintain savannas in a grassy state. These fires are "hot" as they burn the accumulated fuel of a complete growing season at a time when it is dried-out and easily kill mature bush. Furthermore, late in the dry season bush buds are sprouting which makes them more vulnerable to fire. In dense thickets, there is too little grass to fuel a "hot" fire and the resultant "cool" fire hardly damages the bush, while depleting the grazing.

Stem-burning or stump-burning is a fire control method that burns individual encroacher bushes off one-by-one by making a localised fire at the base of every stem. This is a cheap method often used in communal areas or by small-scale farmers.

Limitations

An early dry season fire has less accumulated dry fuel available and thus burns much "cooler" than a late dry season fire. Early dry season fires effectively protect trees and are preferred from a forest management perspective. A late dry season fire has much more dry grass fuel and thus burns "hotter" effectively killing bush.

A fierce fire may kill widely spaced mature encroacher bush outright but it is ineffective against bush thickets and merely singes it around the edges. A bush thicket does not have the dry plant matter needed to carry the fire into the thicket and kill the bush.

How to apply

Natural hot fires can be imitated:

- A dry herbaceous fuel load of at least 2 tons per hectare is required.
- Man-made infrastructure (e.g. fences and pipelines) has to be protected.
- Livestock and wild animals have to be evacuated from the targeted area and provided with alternative forage for the period that the burned area will be without adequate re-growth.
- The planned burn has to be contained to the target area to avoid collateral fire damage.

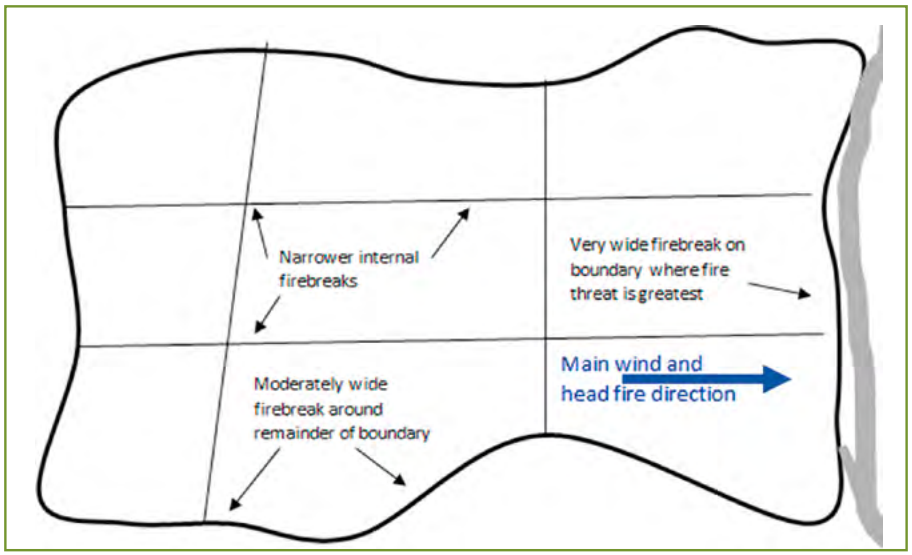


Figure 1:

The area targeted to be burned is surrounded by firebreaks used to light counter (back-) fires that control the main (head) fire. Sometimes, internal fire breaks are constructed as well for emergency fire control.

Any planned burn to counter bush encroachment must be coordinated with the Directorate of Forestry, which can assist with fire control to ensure that the planned burn meets all requirements of its fire policy. Coordination with farming communities and neighbours is also important. Farmers can be held responsible for fire damage on other farms if the fire gets out of control.

The targeted area must be surrounded by fire breaks or use natural features (e.g. river courses and mountain ranges) to restrict the burn to certain areas.

- Most farm fire breaks are ineffective against fierce fires. Fierce fires burning with the wind easily jump 50 metres wide fire breaks as exploding wood particles and airborne sparks are driven over the fire break by the wind.
- The purpose of the fire breaks is to light "backfires" that burn against the wind and head towards the main fire. When these two fires meet, they extinguish each other as all fuel in all directions has been consumed. Backfires that control head fires on the front and sides have to be lit well before the main fire so they can clear an appropriately large area of fuel before the arrival of the main fire.

A fire break (in this case, a mere footpath) is used to light a back fire that burns slowly against the wind (easy to control) and in the direction of the main (head) fire to come, to contain the main fire by burning away fuel around and in front of it. The actual fire break itself would never stop the main fire. Lighting backfires early in the morning when the grass sward is still dew-laden makes it even easier to control as it will burn very slowly and gently.

Costs

While the planned fire itself is cheap, limiting the burn to the targeted area may be quite costly. The greatest cost factors are the fire beaters who steer and direct fire and the firefighting equipment. Such costs are hard to come by but are probably around N$100/hectare. The initial procurement of firefighting equipment is expensive but as it is used against many fires over many years, its unit cost over time is quite low. If the planned fire burns out of control, the damage can be extremely expensive.

Powerful methods of bush control, such as chemical and mechanical control, tend to remove too many woody plants from the land and leave it too exposed to the elements. Rapid re-encroachment may result if rains are good, or desertification if a dry spell follows control. Therefore, farmers should take care to leave enough large woody plants after initial bush control to reduce wild ecosystem swings and the need for perpetual artificial bush control.

3 Aftercare: How to Prevent Bush Re-growth

Aftercare is what needs to be implemented after initial bush control to keep the rangeland in a productive grassy state and prevent re-encroachment. It is an essential component of comprehensive bush control but is, unfortunately, often overlooked. There is a limited choice of aftercare methods, being biological, manual and chemical. These methods are briefly discussed in this chapter.

3.1 Importance of Aftercare

Nature's response to radical bush control is often to compensate by growing more woody replacements. This is seen as re-encroachment. If encroacher bush is thinned less radically, larger individuals suppress smaller ones and less aftercare is required. The time it takes for bush-controlled land to require follow-up is highly variable. It depends on the bush control method used and natural circumstances such as rainfall and soil fertility.

The land manager has to monitor the growth of coppicing bushes and the emergence of woody seedlings to decide when aftercare is required. In bush-controlled rangeland, it is easy to see when aftercare has to be applied.

Situation 1: cut stumps are coppicing
Harvested woody plants were not killed and their cut stumps are coppicing again. Coppicing occurs quickly after bush thinning. This situation can be monitored by casual observation while inspecting the grazing area.

Coppicing stem of untreated plants after harvesting.

Situation 2: seeds of woody plants are germinate

If re-encroachment occurs via establishing bush seedlings, it may take much longer before aftercare becomes essential because a series of above-average rainfall season is needed for re-encroachment from seed. The emergence of woody seedlings is best monitored by fixing a site within a former bush thicket that was thinned or cleared. The site can be situated at a landmark or marked with metal poles driven into the ground. Every year in the late dry season, when most grass has been removed and small woody seedlings are most easily visible, the site has to be inspected. If seedlings are emerging, aftercare has to follow within a couple of years, before seedlings grow higher than grass.

Dozens of *Acacia mellifera* seedlings emerging per square meter. If this event is picked up by regular monitoring, the land manager knows to intervene soon to prevent full-scale bush encroachment.

Aftercare must be part of the Management Plan for any bush control operation to keep the rangeland in a productive, grassy state and prevent re-encroachment.

3.2 Aftercare Methods

In all cases of aftercare, it is small, immature woody plants (mainly low coppice growth and saplings) that have to be removed to return the rangeland to the bush density achieved after first control. In the interest of the environment, it would be best to practice selective aftercare with non-chemical methods that control these small woody plants so that the footprint of the land manager can be minimised.

In exceptional cases the land manager is interested in sustainable harvesting of woody plants. Aftercare for woody re-growth would allow a larger number of woody saplings or cut stems to survive, but at a lesser density and well-spaced out so that they can grow out quickly into large bush with thick wood suitable for further processing. This is achievable with highly selective manual aftercare and pruning of coppice re-growth. Browsing and fire can be relatively unselective and destroy more young woody plants than desirable for sustainable harvesting.

3.2.1 Biological aftercare

Browsers

The most profitable way is to have the sprouting and emerging bush eaten down by browsing animals. Young and small woody plants are entirely within the reach of goats and are very palatable and nutritious and thus readily eaten. Most thorns are not yet hard so that small woody plants are relatively easy to harvest. Goats and other browsing animals are specially equipped to deal with physical and chemical plant defences (e.g. thorns and tannins, respectively). A split upper lip enables goats to grasp small leaves in-amongst the thorns while their saliva and liver contains tannin-neutralising substances that prevents a protein deficiency being induced.

Keeping a large goat flock on bush-controlled land will take care of most re-growth. While containing woody re-growth, goats earn money by producing quality meat. Even though goats are hardy, goat farming is a relatively specialised enterprise and needs to be well prepared for in terms of predator control, kraaling, fencing requirements and herd management. Depending on the browsing pressure, the goats would have to stay on the land for years to continually control woody re-growth.

Domestic and wild browsing animals do utilise encroacher bush but not sufficiently intense to prevent bush encroachment.

Fire

Controlled burning of bush-controlled rangeland to kill off immature, small woody plants and soft-coated seeds in the soil seed bank is a natural/biological method that should be used more often. The planned fire does not need to burn as fiercely as required to contain mature bush. An aftercare fire requires only 1.5 tons dry herbaceous matter per hectare as immature bush is more fire-prone than mature bush. However, the other requirements of planned burning discussed earlier apply to aftercare fires as well. Compared to goat browsing, the advantage of a planned fire is that woody seed and small bush is killed completely but it is more difficult to achieve. Woody re-growth is impeded for a considerable period of time, relieving pressure on the land manager.

➜ A combination of the occasional planned fire and intensified browsing pressure should keep most re-encroachment in check.

3.2.2 Manual aftercare

Small bush and saplings are easily removed by chopping them off about 10 cm below ground level, thus killing the whole plant. This aftercare method is quick and easy even on hard ground because the targeted woody plants are small. However, it is very difficult to control coppicing cut stems in this manner so that the method is less appropriate for situations were woody re-growth is caused by coppicing stems. One worker alone can apply manual aftercare to a large area (several hectares) each day, depending of course on the density of emerging woody plants. The biggest drawback of manual control is that some saplings may be overlooked.

3.2.3 Chemical aftercare

Includes foliar spraying of coppicing bush, seedlings and saplings and the chemical treatment of cut stumps. This method should be applied with great care to avoid a worsened case of bush re-growth.

3.3 What comes after Aftercare?

In most cases in Namibia, bush encroachment is caused by inappropriate land use non-adaptive grazing and unsustainable rangeland management. Controlling encroacher bush treats the symptoms of the problem, not its cause. To address its cause and prevent bush encroachment recurring, land management practices have to change to become more sustainable.

Sustainable rangeland management

Namibia's National Rangeland Management Policy and Strategy (2012) is a farmer-driven policy. It emphasises widely applicable "principles of sound rangeland management" rather than set rules and regulations. These principles recognise ecosystem health at the core of rangeland management. The implementation of the policy is organised voluntarily through farmers' unions and farmers' associations.

Implementing the policy's eight principles of sustainable rangeland management will enable the land user to utilise rangeland sustainably and avoid the danger of man-made bush encroachment. It can still happen due to natural drivers, but it will be much less frequent and probably more manageable. The eight principles of sustainable rangeland management are:

1. **Know the resource base:** Know the perennial species of grass that naturally dominate in your area and ensure their continued vigour and abundance. This also requires knowledge of soil, nutrient hotspots and general rangeland ecology. Know the bush, its density and impact. Use indicator species to realise if rangeland is degrading, stable or improving.
2. **Manage grasses for effective recovery and rest:** This is the most important principle of adaptive grazing management. Perennial and preferred species of grass are usually grazed first and most intensively. They need to recover from previous grazing completely until they have set seed before being grazed again.
3. **Manage for effective utilisation of grasses and shrubs:** Grazing should stimulate grass production and not inhibit it. Grazing domestic livestock like cattle and some sheep breeds do not browse much. The browse component of a savanna rangeland is under-utilised while the herbaceous (grassy) component usually is over-utilised. Browser-based livestock enterprises are encouraged.

4. **Enhance soil condition:** For grasses to flourish, the top layer of soil has to be in good condition, allowing rainwater to infiltrate easily (proper water cycle) and binding plant nutrients so they do not leach out (proper mineral cycle). This is achieved mainly by keeping the soil well covered with living plants or mulched with dead plant litter to prevent soil erosion by wind or water.
5. **Control bush encroachment:** As discussed in this manual.
6. **Plan for droughts:** By timeous reduction of the livestock stocking rate in synchrony with the advancing fodder deficit. Grow more fodder to compile a fodder bank to be used during a drought.
7. **Monitor the resource base**: By keeping a variety of records of the veld that inform rangeland management. The establishment of woody seedlings is an important indicator of the transition to a bushy state, requiring management intervention.
8. **Plan land use infrastructure:** To make sustainable rangeland management easier, e.g. by providing enough camps per herd of livestock to facilitate effective rotational grazing management that allows perennial indicator grasses to recover from grazing.

A look at the land after bush control

A diverse landscape

The treated landscape should not appear homogenous. After bush control, there should be thicker patches of bush (mostly on more fertile soil, near seasonally-wet depressions, south-facing hill slopes, etc.) and thinner patches (on infertile soils and in exposed, hot, windy locations such as plains and north-facing hill slopes). A mosaic of landscapes favours higher biodiversity that is more resilient to negative environmental impacts like climate change.

There should be a mix of tree and bush species and an adequate number of large trees that suppress woody saplings by competitive suppression.

Leave the occasional bush clump of 1 to 4 hectares intact for the sake of providing shelter for those animals who seek it in dense bush clumps.

Minimal soil disturbance

Bush control on steep slopes should be done extremely cautiously to avoid soil erosion. Brush-pack woody fines on the contour to avoid soil erosion, or leave contour strips in place.

Leave woody fines on the land to improve soil organic matter, moisture and nutrient levels and reduce erodibility and enhance the germination and establishment of grasses.

Rich grass

Where grass growth was stunted by dense bush, a "grass explosion" often occurs after bush control. Such an explosion tapers off after about 7 years because the grasses have depleted the residual soil fertility left when encroacher bushes were removed. The level at which grass production stabilises depends on the number of bush left intact, as woody plants improve soil fertility. It also depends on the abundance and vigour of perennial grasses in the post-bush grass sward: the more perennial grasses managed to establish in bush-controlled veld, the more stable its long-term grass yield and nutritive value.

Bush thinning alone does not alter the botanical composition of the grass sward. Too often, only those ephemeral, opportunistic grass and weed species that managed to survive bush encroachment are the only herbaceous species left. They flourish but form an unstable layer with too few nutrients to maintain grazing animals throughout the year. Long-lost perennial grass species often have to be re-introduced artificially to improve the grass sward permanently. Only then will the post-bush grass yield stabilise at a relatively high level, offer more acceptable nutrition to grazing animals (i.e. reduce the need for nutrient-dense licks) and contribute to a better spatial distribution of grazing animals.

If the grass sward on the treated land is very poor, it may be advisable to initially leave more bush than desired to ensure an adequate feed supply to the animals and only thin it to the ultimate density once the grass sward has recovered.

Useful contacts

CONTACT	VALUE/FUNCTION
De-bushing Advisory Service Namibia 061 429 256 info@dasnamibia.org www.dasnamibia.org	A national information sharing and capacity building platform for providing advice to farmers on sustainable bush control and value addition opportunities. The website has a number of downloadable documents, videos, and other information, relevant to decision making regarding bush encroachment.
Namibia Biomass Industry Group (N-BiG) 061 371 196 info@n-big.org www.n-big.org	A non-profit organisation, representing all businesses that harvest and process bush-biomass in the country. Support members to access markets and conduct trainings on how to utilise harvesting machines among others.
Namibia Charcoal Association (NCA) 067 304 220 info@ncanamibia.com www.ncanamibia.com	A non-profit voluntary membership Association created to serve the charcoal industry in Namibia from producers and processors to suppliers and all other stakeholders. Provide professional support to charcoal stakeholders with respect to the implementation of environmental and social standards, quality assurance, market identification, modernisation of production, advocacy and public communication. Aims to strengthen the charcoal industry in a sustainable manner.
Ministry of Agriculture, Water and Forestry: Directorate of Forestry (DoF) Head office: 061 208 7111 www.mawf.gov.na	Responsible for issuing of permits for harvesting, transporting, exporting and marketing of forest resources, including from bush encroaching species. Website includes downloads for applicants, explanation of requirements outlined in the Forest Act (2001). Various reports and articles of relevance to bush harvesting.
Ministry of Agriculture, Water and Forestry: Directorate of Agricultural Research and Development (DAPEES) Head office: 061 208 7111 www.mawf.gov.na	"Promote the adoption of improved agricultural technologies and practices in order to increase agricultural production..." including advisory and training services to farmers.
Ministry of Environment and Tourism (MET): Directorate of Environmental Affairs Head office: 061 284 2111 www.met.gov.na	Responsible for issuance of Environmental Clearance Certificates for bush harvesting projects.
Agri Advisory Services 061 207 4265 www.agribank.com.na	Previous known as Farmers Support Project, this advisory service of Agribank provide mentorship and trainings on rangeland management, livestock, crop and horticulture production to Agribank clients in all 14 regions.
Namibia Agricultural Union (NAU) 061 237 838 nau@agrinamibia.com.na www.agrinamibia.com.na	Umbrella organisation of Namibian farming communities to promote a conducive environment for sustainable agriculture.
Namibia National Farmers Union (NNFU) 061 271 117 info@nnfu.org.na www.nnfu.org.na	A mouthpiece for Namibian communal and emerging (NECFU) farmers. Aims to improve food production in these systems.

Glossary of key terms

A

Adjuvants: soaps, stabilisers, colorants and similar chemicals that are added to arboricides for other purposes than killing plants. They are not chemically inert and may damage the environment.

Alkaloids: a group of naturally occurring chemical compounds produced by plants to protect themselves. Most of them have a bitter taste and may be harmful to humans and animals.

Annual: a plant which completes its life cycle within one year and then dies after flowering.

Animals:

- ***Foraging*** animals search for food.
- ***Ruminants*** ferment plant-based food in a specialised stomach prior to digestion such as cattle, goats, sheep, giraffes, antelope.
- ***Grazers:*** animals feeding on grass or other lower vegetation such as sheep and cattle. Grazers target the vegetation by clipping plants off at ground or near to the ground level.
- ***Ungulate browsers:*** diverse group of primarily large mammals that includes odd-toed ungulates such as horses and rhinoceroses, and even-toed ungulates such as cattle, giraffes, hippopotami.
- ***Lagomorphs*** (rabbits and hares) eat plants.
- ***Rodents*** (mice, rats, porcupines) will eat both meat and plants.

Aquifer: an underground layer of water-bearing rock, gravel, sand or silt. Usually deep in the soil and out of reach of many plants that do not have long taproots.

Arboricides: chemicals used to kill woody plants such as encroacher bush. They are a type of herbicide (chemicals that kill plants) designed specifically to kill woody plants (although they kill herbaceous plants too). They can damage the environment if used unselectively, off-target and near water. Harmful to minor life forms (e.g. microbes, bees) but harmless to large mammals (e.g. livestock, man).

B

Biodiversity: refers to the variety of organisms in ecosystems. Biodiverse ecosystems can better withstand and recover from destructive events.

Brush-pack: packing bush or bush parts on the contour to impede the overland flow of water and reduce soil erosion.

Bush control: this manual assumes that the most common objective will be to restore rangeland to a productive, grassy state that enables optimum livestock production. Bush is an integral part of Namibian rangelands and controlling it implies its careful thinning and not clear-cutting or eradication. 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 equivalent: a "bush equivalent" (BE) is a standardised, 1.5 m high. E.g. If this bush is an *Acacia mellifera*, it transpires about 39 litres of water per day (re-calculated from De Klerk (2004) Bush Encroachment in Namibia.

Bush thinning: thinning refers to the selective removal of bush, leaving enough large individuals to suppress small individuals to repair and stabilise the grass:bush balance.

C

Coppice: new growth from the stump or roots after the plant has been cut down.

Contour strips: refers to leaving bush strips on steep slopes during felling to prevent soil erosion.

D

Deciduous: trees or shrubs that shed their leaves seasonally. The opposite of evergreen.

Desertification: land degradation in which a relatively dry area of land becomes increasingly arid, typically losing its bodies of water as well as vegetation and wildlife.

Dystrophic: low concentrations of plant nutrients in the soil to support abundant plant life. The opposite of eutrophic.

E

Ephemeral herbs: grows only for a short time, and then die off. Survive by making plentiful seeds resulting in weed growth.

Evergreen: having leaves throughout the year, not deciduous.

G

Grasses:

- Grass sward: a top ground layer containing a continuous (in mesic areas) or discontinuous (in arid areas) mat of grass and grass roots.
- Perennial grass: a perennial is a grass that lives for more than two years and is less dependent on seed production than annual grass.
- Climax and pioneer grass: bare soil is colonised by grass species in succession (after another). Pioneer species have a short life (annuals). At the next stage more stable, longer-living sub-climax grass species grow. The final stage is reached when the climax grasses that are usually palatable and nutritious replace the weed-like pioneers. Indicator grasses show whether rangeland condition is degrading, stable or improving.

Grass vigour: the number, size and condition of (perennial) grass tufts.

H

Holistic management: a whole farm planning system that helps farmers, ranchers and land stewards better manage agricultural resources in order to reap sustainable environmental, economic, and social benefits.

I

Indigenous: originating or occurring naturally in a region or environment, not introduced.

Isohyet: line on a map connecting places of equal rainfall in a certain period of time.

L

Legume / leguminous: a plant that use root nodule bacteria in symbiosis to fix nitrogen in the soil. Well-known legumes are alfalfa, clover, peas, beans, lentils, whose seeds, fruit and pods are usually more protein-rich than those of non-leguminous plants.

M

Mega browsers: refers to larger animals that feed mainly on leaves and stems which are far of the ground, animals such as elephants, black rhino and giraffes.

Microphyllous plants: these are plants that have small leaves, unbranched leaf veins. The opposite of macrophyllous plants.

P

Palatable: tasty.

S

Savanna: a mixed woodland ecosystem made up of grassland with scattered trees that is found in tropical and sub-tropical regions.

Seed-set: when grasses flower and start making seeds, but before seeds are ripe.

Shrub: a many-stemmed, woody plant of relatively low height.

Soil erosion: the wearing away of the top soil, rock, or dissolved material mainly by water or wind. Apart from scarring the landscape, erosion dries out the soil and reduces plant productivity.

T

Tap root / lateral root system: there are two main types of roots. Tap roots grow deep and enable the plant to anchor better in the soil and obtain water from deeper sources. Lateral or fibrous roots extend to the side. They are more vulnerable to drought but quick to absorb surface water.

Tannins: tannins are released by plants being browsed, to deter browsing. They impart a bitter taste to forage, making it less palatable. They complex dietary protein and make it less digestible, possibly to the extent that the animals suffers an induced protein deficiency.

Tree: a woody plant of considerable size when fully grown and usually with a single main trunk in evidence.

V

Value addition: relating to, or being a product whose value has been increased especially by special manufacturing, marketing, or processing.

W

Woody sapling: a young tree, especially one with a slender trunk.

Woody seedling: a very young plant that has grown from a seed.

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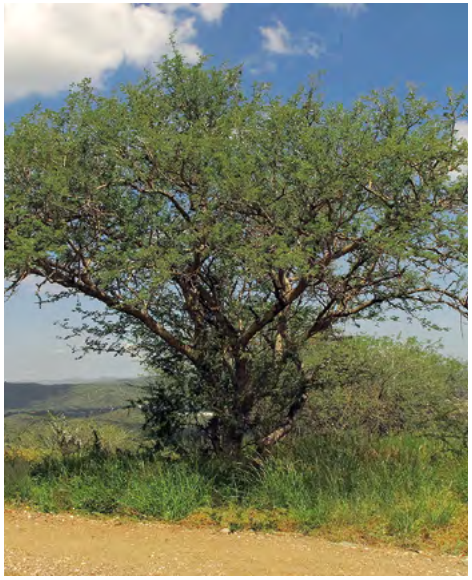
Summary of main encroacher plant species in Namibia

The preferences and characteristics of the main encroacher species can easily be observed in the field. However, it is not yet well-understood what causes a certain species to become dominant in a certain area. The table below provides an overview of some of the bush species considered to be problematic in Namibia.

For a detailed botanical description of encroacher woody species, the reader is referred to regular field guides or botanical handbooks such as B. Curtis and C. Mannheimer's book "Tree Atlas of Namibia", 2005.

SPECIES	PROPERTIES	VALUE / USAGES	CONTROL METHODS
Acacia erubescens (Senegalia erubescens) Yellow-Bark Acacia, Withaak, Omungongomwi, Omugumba   	• Dominant encroacher species in western Namibia. • Has a whitish-yellowish appearance. • Has a flaking, papery bark. • Seeds are soft-coated, life cycle and properties are similar to *A. mellifera*. • Grows well on poor (dystrophic) rocky soils. • Leguminous.	• Nutritive value of leaves is high but is extremely thorny and difficult to browse. • Makes good charcoal. • Makes fence droppers although the wood is not insect resistant.	• Coppices when felled. • Easily controlled by digging out the root stump. • Very susceptible to poisoning. • Easily killed by fire when still small.

SPECIES	PROPERTIES	VALUE / USAGES	CONTROL METHODS
Acacia mellifera (Senegalia mellifera) Black Thorn, Swarthaak, Omukono, Omusaona   	• Medium height, usually 5-7 metres tall, compact form and a flattish or rounded crown. • One of the first trees to come into flower, producing small 'powder puff' balls in white, cream or pinkish. • Deciduous, very thorny, hooked thorns are black. • Flat, papery bean pods, soft-coated seeds. • Prefers fertile soil. • Large trees suppress the growth of young trees near their canopy. • Grows alll over Namibia except in Namib Desert. • Leguminous.	• Wood has high calorific value, larger specimens make excellent charcoal. • Pods of are not fleshy but still palatable and well eaten by animals. • Small leaves are highly nutritious for animals but difficult to harvest.	• Most easily controlled by felling but coppices readily, especially the thinner stems. • Can be dug out if the soil is sandy. • Can be controlled by burning as long as it is small. • Is easily killed by / very susceptible to arboricides.
Acacia reficiens (Vachellia reficiens) Red thorn,Rooihaak, Omutsiyatsi, Omugondo    *Acacia luederitzii (Vachellia luederitzii)* Kalahari Acacia, Baster haak-en-steek,Omushu   	• Life cycle and properties similar to *A. mellifera*. • Thorns in pairs, hooked or straight. • Leaves, flowers, bark and unlignified branch are browsed by a variety of animals. • Leguminous. • Very difficult to distinguish in field.	• Very good for animal food. • Wood is relatively soft.	• React like *Acacia mellifera (Senegalia mellifera)* to control methods. • Are easily controlled by digging out the root stump. • The species are very susceptible to arboricides.

SPECIES	PROPERTIES	VALUE / USAGES	CONTROL METHODS
Colophospermum mopane Mopane, Mopani, Omusati, Omutati   	• Grows in the north-west and north-east but not in the Kavango region. • Protected species that encroaches in disturbed areas. • Single-stemmed individuals should not be controlled. • Multi-stemmed bush form may indicate encroachment if not growing on shallow, highly alkaline soil. • Leguminous but does not fix Nitrogen in soil.	• Leaves are main feed source of caterpillars which are a delicacy for local people. • Wood is exceptionally hard with a high calorific value, is used in construction and fencing.	• Never remove a single-stemmed tree. • Coppices readily when felled. • Best controlled by chemical or mechanical means as manual control can easily result in re-growth. • Always consult DoF for controlling this species.
Dichrostachys cinerea Sickle Bush, Sekelbos, Ongete, Omutjete   	• Mainly in central, northern and north-eastern Namibia. • Can form dense, impenetrable stands of up to 12,000 plants/ha. • Usually a multi-stemmed small tree, tangled appearance. • Leaves have very fine leaflets. • Curly seed pods in tight bunches. • Hard-coated seeds are not destroyed by digestion and are spread by animals. • Plant also grows easily from root suckers. • Leguminous.	• Makes excellent charcoal. • Good for fence droppers as it is resistant to termites. • Pods are very palatable and eagerly eaten by livestock.	• Often ineffectively to controlled by felling, digging out or burning, as this stimulates vegetative growth. • Germination is stimulated by increased light intensity; seeds are more likely to germinate when the thicket is cut. • Best controlled by chemical means. • Often requires more than one treatment. • Most arboricides have to be applied at double the usual concentration as it is more tolerant of plant poisons than *Acacias*.

SPECIES	PROPERTIES	VALUE / USAGES	CONTROL METHODS
Rhigozum trichotomum Three-Thorn, Driedoring, Okatakambindu   	• Limited distribution but main encroacher in southern Namibia. • Hardly ever grows taller than 2 metres. • Not leguminous.	• Stems are thin (<3 cm in diameter), wood not profitable to harvest. • Flowers are very palatable but leaves offer little feed to small ruminants.	• Grows from a creeping rootstock so manual and mechanical control is generally ineffective. • Digging-out only effective in spring, when plant's starch reserves are low. • Chemical control is most effective for this species.
Terminalia sericea Silver Cluster-leaf, Sandgeelhout, Omugolo, Omusejasetu   	• Single-stemmed tree (not a bush) grows only in the North East. • Limited to dystrophic (less fertile) sandy soil. • Limited distribution makes it an encroacher species of lesser importance. • Not leguminous.	• Straight poles for fencing. • Wood is said to be termite-resistant. • Not very good animal fodder.	• Tree does not coppice readily and is easily controlled manually or mechanically.

List of common protected plant species in Namibia

Protected species are those that have been extensive over-utilised and/or have high ecological value as listed in Forest Act, 2001 (Act no.12 of 2001) and Forest Regulation 2015.

These species should not be harvested as part of bush thinning initiatives alternatively, only in consultation with DoF. For a complete list of all protected plant species, please refer to the Forest Act.

SPECIES	PROPERTIES	VALUE / USAGES	CONTROL METHODS
Acacia erioloba Camelthorn, Kameelboom, Omuthiya, Omumbonde   	• Commonly found in bushveld and grassland and usually on deep sandy soil or long watercourses in arid areas. • Has a medium or large-shaped crown. • Has golden-yellow flowers scattered along the branches. • Has velvet grey, large, thick and semi-woody pods, hard-coated seeds. • Leguminous.	• Pods are eaten by stock and game and can be collected and sold. • Wood is very strong and durable.	• Often scattered amongst encroacher bush and should remain standing. • Densifies in north-eastern Namibia in response to over-grazing or felling of old (huge) specimen. • Control should only be in consultation with Forestry Directorate. • Very susceptible to arboricides.

SPECIES	PROPERTIES	VALUE / USAGES	CONTROL METHODS
Albizia anthelmintica Worm Cure Albiza, Aroeboom, Omupopo, Omuama   	• Thorny/spiny, deciduous, multi-stemmed, medium canopied tree, about 8m high. • Smooth, gray to brown bark. • Flowers usually on leafless twigs. • Straw coloured, papery, pointed pods. • Seeds are round and flattened.	• common medicinal use for deworming.	• Protected species that should not be controlled. • Densifies in response to overgrazing but limited by slow growth and high palatability. • Very susceptible to arbori-cides.
Boscia albitrunca Shepards tree, Witgatboom,Omunkuzi, Omungwindi   	• Commonly found in semi-desert area and bushvelds. • Small tree with a rounded, much-branched crown. • Evergreen with pale grey stems. • Bark is smooth, grey to whitish. • Leaves stiff and leathery. • Flowers in dense clusters on short lateral shoots and small, yellowish green without petal. • Hairless, yellowish berries, about 10mm in diameter. • Often grows under thorny trees that protect it till maturity ("nurse trees").	• Heavily browsed by game and livestock; valuable fodder for livestock in times of drought. • Roots are edible (pounded and made into porridge or roasted and used as a substitute for coffee or chicory). • Leaves and roots are used as medicine.	• Often scattered amongst encroacher bush and should remain standing. • Protected species that should not be controlled. • Does not densify. • Tolerant of arboricides. • Coppices readily

SPECIES	PROPERTIES	VALUE / USAGES	CONTROL METHODS
Burkea africana Wild seringa, Sandsering, Omutundungu   	• Dystrophic sandy soils in dry deciduous bushveld and woodlands; widely distributed in tropical Africa and in sub-tropical regions southwards to Namibia. • Medium-sized, spreading, flat-topped tree up to 8 m high, deciduous. • Silvery leaves 100–350 mm long; leaflets oval and silvery when they are young and marked with brown spots. • Flowers are creamy white and fragrant.	• Bark is toxic, rich in alkaloids and tannins and used for tanning leather.	• Protected species that should not be controlled. • Does not densify. • Valuable timber tree species.
Combretum imberbe Leadwood, Hardekool, Omukuku, Omumborombonga   	• Almost white trunk and gigantic main branches. • Medium to large, semi-deciduous tree, up to 20 m high. • Extremely slow growing. • Snake skin type of bark. • Yellowish cream-coloured flowers with sweet fragrance. • Prefers moist patches (e.g. omiramba).	• Wood has high calorific value. • Religious and medicinal value.	• Protected species that should not be controlled. • Densifies in response to overgrazing but limited by slow growth and high palatability. • Very susceptible to arboricides. • Valuable timber tree species.

SPECIES	PROPERTIES	VALUE / USAGES	CONTROL METHODS
Commiphora cf. glandulosa Corkwood/Kanniedood   	• Multi-stemmed shrubs or trees with stems branching repeatedly at ground level, or trees with a single upright stem, often spiny, with smooth or papery bark. • Species from arid areas often have a swollen, nearly succulent trunk. • Leaves vary between simple and compound. • Has small white flowers. • Deciduous and for most of the year without leaves. • Bark of most species peels off in papery pieces and flakes, often with a greenish layer underneath.	• Historical and biblical association as providers of the earliest healing balms and fragrances.	• May densify in north-west in response to overgrazing. • Small specimen easily destroyed manually.
Peltophorum africanum African wattle, Huilboom, Omupalala, Omuparara   	• Commonly found in bushveld often on sandy soils. • Small to medium sized tree with a dense crown. • Young shoots densely covered with fine, rusty brown hair. • Has feathery leaves and yellow petals. • Pods are flat, winged, with fine velvety hair.	• Leaves are browsed by game. • Bark and roots are used for medicinal purposes. • Wood is suitable for carving. • Several butterflies breed on the tree, sap-sucking insects known as spittle bugs occur in large number on the branches during certain times of the year.	• Protected species that should not be controlled. • Hardly ever densifies and if, only very small areas (<100m^2) are affected.

SPECIES	PROPERTIES	VALUE / USAGES	CONTROL METHODS
Philenoptera nelsii Kalahari Apple leaf, Apelblaar, Omupanda   	• Commonly found in hot dry bushveld often on deep sand. • Small to medium-sized tree with yellow autumn colours. • Has a yellow bark. • Has large, dark green, leathery leaves, velvet when young and less hairy with age. • Beautiful blue flowers in spring. • Not leguminous.	• Both leaves and seeds are very palatable, it is a prime fodder tree. • Wood is very tough and flexible, was used for making ox-wagon wheels.	• Protected species that should not be controlled. • May densifies in overgrazed rangeland but affects small areas (<1 ha). • "Thickets" easily are penetrated by browsers.
Sclerocarrya birrea Marula, Maroela, Omungongo,Omukongo   	• Species is widely distributed in Northern Namibia. • Medium to large tree, usually 9 metres tall, but can grow up to 18 metres high. • Single-stemmed with a dense, spreading crown, deciduous.	• Drought resistant species. • Yields exceptional fruit per tree, up to 500 kg per year. • Wood has been traditionally used for carving pestles and mortars, bowls, drums, beehives and stools and even canoes.	• Protected species that should not be controlled. • Does not densify. • Valuable fruit tree species.

Notes

Bush Control Manual

Bush encroachment is an enormous and complex challenge for Namibian farmers. The phenomenon affects more than 30 million hectares of prime savannas and is mostly concentrated in the central and eastern regions where intensive cattle farming is prevalent. Densities vary between 2,500 and 10,000 bushes per hectare. The woody biomass offers substantial potential for value addition. The production of wood chips, charcoal, compressed firewood and animal feed are such opportunities.

In recent times, a range of bush control methods were developed and tested. This manual gives an overview of different approaches to bush control such as manual and semi-mechanised, mechanised, biological and chemical methods and discusses their strengths and challenges. It provides land managers with tools to analyse and monitor bush encroachment. The manual encourages farmers to manage their land with a long-term perspective, including aftercare and sustainable rangeland management. It further promotes selective bush thinning rather than total clearing of land.

A list of further reading and useful contacts can also be found in this manual for advice on bush control.

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