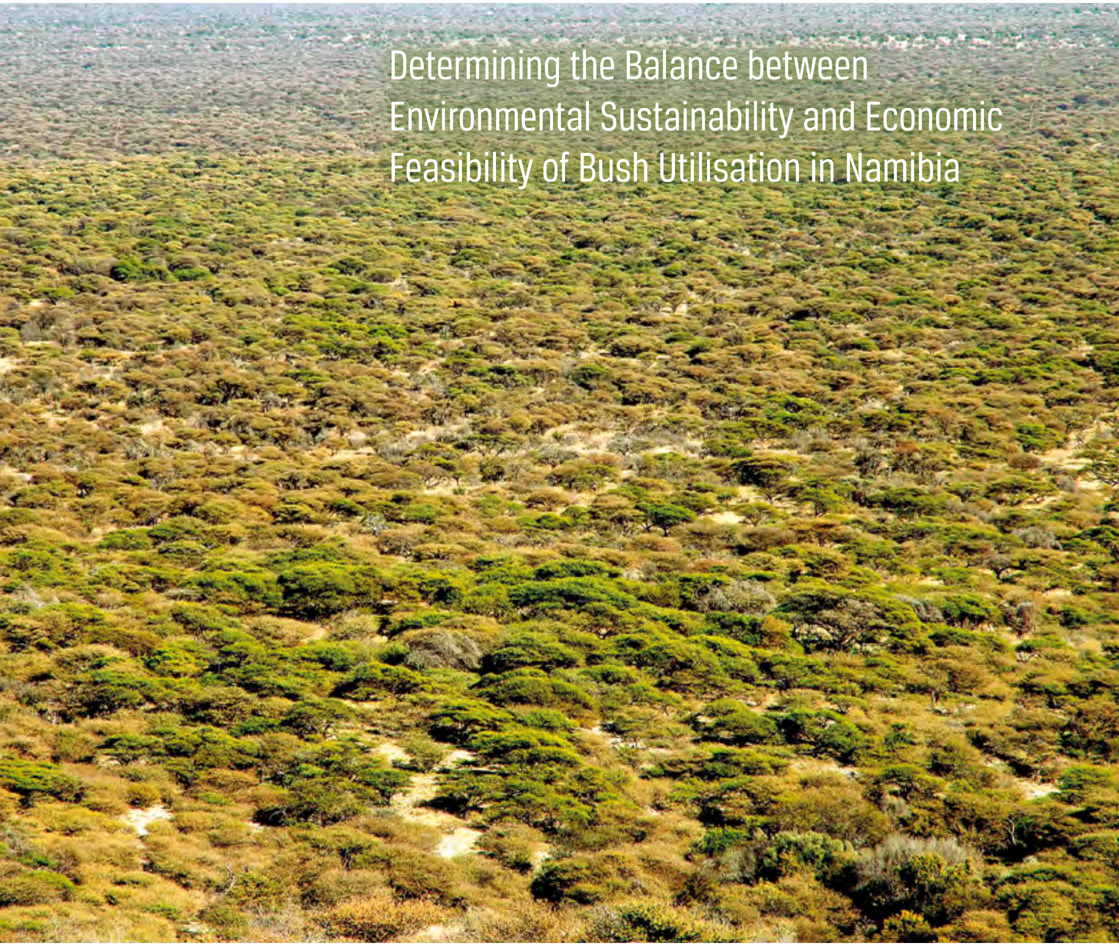
Support to
De-bushing
Project

Beyond Bush

Quantifying
Harvestable Encroacher Bush



Determining the Balance between Environmental Sustainability and Economic Feasibility of Bush Utilisation in Namibia

UNITY LIBERTY JUSTICE

25 YEARS german cooperation
DEUTSCHE ZUSAMMENARBEIT

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

Introducing the **Support to De-Bushing** Project

Namibia is affected by bush encroachment on a massive scale. The phenomenon currently affects some 26 to 30 million hectares of farmland in 9 of the country's 14 regions. That amounts to roughly 30 per cent of Namibia's land area. Bush encroachment has lowered the livestock capacity of rangeland by up to two thirds. It further results in severely reduced biodiversity and limits the recharge of groundwater.

Despite the negative impacts, **the encroacher bush has developed into a huge biomass resource,** estimated at about 200 to 300 million tonnes. Measures used to combat bush encroachment create positive opportunities for the Namibian economy, such as the use of the resource for electricity generation and value chain development in other sectors. De-bushing therefore offers the potential to increase agricultural productivity, economic growth, employment and energy security, without competing with food production.

In line with the Fourth National Development Plan (NDP4) and the National Rangeland Management Policy and Strategy of 2012, **the Support to De-bushing Project** aims to strengthen the restoration of productive rangeland in Namibia. It identifies value chain opportunities to trigger large-scale de-bushing activities. Its focus is closely aligned to the National Industrial Policy of 2012 and the Growth at Home Strategy, which promote domestic value addition for local resources. The project will foster institutional development in the biomass sector and provide support to improve the legal and regulatory framework for large-scale bush control.

The Support to De-bushing Project runs from 2014 until 2017 and is a bilateral cooperation between the **Namibian Ministry of Agriculture, Water and Forestry (MAWF)** and the **German Federal Ministry for Economic Cooperation and Development (BMZ).** It is implemented by the **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH**.

Support to
De-bushing
Project

Quantifying Harvestable Encroacher Bush

Determining the Balance between Environmental Sustainability and Economic Feasibility of Bush Utilisation in Namibia

WHAT IS THIS BROCHURE ABOUT?

This brochure presents a **methodology for the quantification** of Namibian encroacher bush and **proposes a practical solution** for balancing environmental sustainability with the economic feasibility of biomass utilisation projects.

It is based on the study "Detailed assessment of the biomass resource and potential yield in a selected bush encroached area of Namibia" (2015), compiled by G.N. Smit (Dept. of Animal, Wildlife and Grassland Sciences, University of the Free State, Bloemfontein, South Africa), J.N. de Klerk (Windhoek, Namibia), M.B. Schneider (DRFN-Desert Research Foundation of Namibia, Windhoek, Namibia), J. van Eck (Windhoek, Namibia).

TABLE OF CONTENTS

The Problem of Bush Thickening

The excessive increase of indigenous woody species has caused a decline in grazing capacity of Namibian savannahs. Restoration measures need to be ecologically responsible and economically justifiable.

Definition

In Southern Africa the phenomenon of the increase in woody plants is commonly referred to as "bush encroachment", though the term "bush thickening" is more appropriate. Bush thickening can be defined as the excessive increase in density and cover of one or more indigenous woody species that exploit disruptions of the grass/bush balance at the expense of grasses. It involves indigenous woody species occurring in their natural environment and is thus mainly associated with the savannah biome.

Savannahs are constrained by rainfall, temperature and soil, as well as by disturbances such as fire and herbivory. Due to the water-limited nature of savannahs, bush thickening is considered a major factor contributing towards the low occurrence or even, in severe cases, total absence of herbaceous plants.

Consequences

The grazing capacity of large areas of the Southern African savannah is reported to have declined due to bush thickening, often to such an extent that many previously economic livestock properties are now no longer economically viable.

Bush thickening has long been considered a serious ecological and economic problem in the rangelands of Namibia and the area affected by bush thickening in the country is estimated to be approximately 260 000 to 300 000 km^2. Removal of some or all of the woody plants will normally result in an increase in grass production and thus also in grazing capacity. However, the results of woody plant removal may differ between vegetation types, with the outcome determined by both negative and positive responses to bush removal. Cognisance must thus be taken of the ecological importance of woody plants in savannah ecosystems.

Requirements for De-Bushing

Positive contributions of woody plants include food for browsers and soil enrichment that elevates the soil nutrient status on a landscape level. A further aspect that is becoming increasingly important is the wood component of bushes and shrubs as a source of energy which includes firewood, charcoal, biofuel and electricity generation. In view of the often poor understanding of savannah ecosystem functioning, finding solutions to the problem – especially long-term solutions – is often difficult.

Restoration of bush thickened areas should comply with two important requirements before they can be considered successful. They should be ecologically responsible and economically justifiable. In Southern Africa, judged on these two basic requirements, it is conceived that very few attempts at restoring bush thickened can be considered successful. This is either because the cost is too high or the wrong approach was followed. Results then are the loss of beneficial woody plants and re-encroachment, often resulting in a state that is worse than before treatment.

PICTURES

1

An area with a dense stand of woody plants demonstrating the extend of bush thickening in many parts of the southern African savannah.

2

Exposed root system of an *Acacia mellifera* bush demonstrating the extensive, shallow root system of the plant that enables it to absorb water over a large area and compete directly with shallow rooted grass plants.

3

Due to the water-limited nature of many savannah ecosystems bush thickening is considered a major factor contributing towards the low occurrence or even total absence of herbaceous plants in severe cases as demonstrated by this dense stand of *Acacia mellifera* bushes.

Biomass Estimations

Various structural classifications of woody plants as shrubs, bushes and trees have been used to describe African savannah woody plants, often with diverse criteria as to whether a plant is a shrub, bush or tree.

Density data (plants/ha) are commonly used in Southern Africa, including Namibia, to describe bush communities, but due to size differences density data are generally inadequate to quantify biomass accurately.

Accurate estimates of above-ground woody biomass of woody plants are essential for a number of reasons:

- for the study of savannah structure
- productivity estimates
- carbon sequestration
- impact of different land-use practices
- for assessing structural and functional attributes of forest ecosystems
- for quantification of resources such as wood fuel and timber

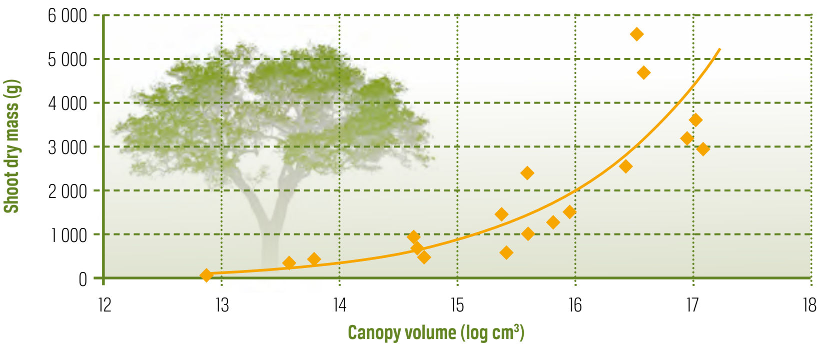
Methods

Biomass can be determined by direct or indirect methods. The most obvious direct measurement of bush biomass involves harvesting a representative number of bushes that include all size classes, oven-drying the material and weighing it. This approach can be costly and impractical, especially when dealing with numerous species and large sample areas. Indirect methods involve the use of allometric regression equations that predict the biomass non-destructively from measurements of the plants such as trunk diameter and crown diameter or measurements from which the spatial canopy volume can be calculated.

RELATION

between **PLANT CANOPY VOLUME** (independent variable) and
SHOOT DRY MASS < 5.0 mm (dependent variable) of *Acacia karroo*

$\ln y = -6.02209 + 0.856029$, $r^2 = 0.86$, $r = 0.93$, $n = 0.93$, $n = 20$, $P < 0.001$



Precise estimates of the harvestable biomass quantity in a given area are a prerequisite for investment decisions of biomass processors and end-users

In the instances where actual biomass figures of woody plants were published, the data are obviously accurate, but extremely time consuming and labour intensive to obtain. What is needed is an accurate and non-destructive technique that can provide estimates of woody biomass prior to any harvesting to enable viability studies and planning.

The most appropriate approach to biomass estimations in Namibia will be the use of biomass allometric equations. Such a non-destructive technique was used in this study.

QUANTIFYING BIOMASS

A quantitative description of woody plant communities that aimed at aiding studies on grass–bush competition interactions, bush thickening and estimation of food to browser herbivore species was proposed as early as 1989. It evolved as the BECVOL-model (acronym for 'Biomass Estimates from Canopy Volume') and this model initially provided estimates of leaf volume and leaf dry mass only. The need for accurate estimations of the wood component was addressed in the recent development of the BECVOL 3-model.

Complete bushes of a number of savannah bush species were harvested and separated into specific biomass fractions, dried and weighed: leaves, shoots and stems in three diameter classes (< 0.5 cm, >0.5–2.0 cm and >2.0 cm). Regression analyses were applied and highly significant regressions ($P<0.001$) were achieved with the curvilinear regression models (exponential and multiplicative) that yielded the highest correlation coefficients. With the incorporation of these regression equations into the BECVOL 3-model, it is now possible to make accurate estimations of the wood component of bushes and shrubs from specific measurements of the plants in a transect.

Study Area and Species

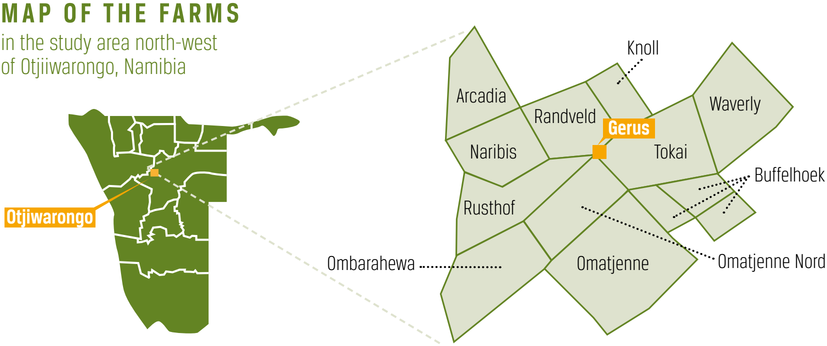
The study area is located north-west of Otjiwarongo in the north-central plateau of Namibia. The dominant vegetation type is thorn-bush shrub land. The focus was primarily on privately owned commercial farms in close proximity of NamPower's Gerus substation.

Eight commercial farms were included in the study. Combined, these farms represent an area of approximately 45 000 ha. Subsequently a total of 28 plots were selected and surveyed during the time allowance granted by the project for field work. The research team relied on the extensive local knowledge of the various farm owners who accompanied the research team to potential survey sites. Past management histories as conveyed by the farm owners were also taken into consideration. The 28 plots were subsequently selected based on all the resources available to the research team to ensure the best possible representation of soil, vegetation type and available biomass in the area.

All the commercial farms are primarily used for extensive cattle farming, with only a limited number of small stock (sheep and goats). Free ranging game species such as springbok, gemsbok, red hartebeest, kudu and warthogs are still common on all the farms. As extensive cattle farms, the productivity of the natural vegetation – specifically the grasses – is critical to the success of these farming enterprises. Thus, they are heavily dependent on annual rainfall. The long-term annual rainfall of the area is approximately 457 mm. The rainy season usually extends from October to April inclusively, but rainfall is irregularly distributed and unpredictable. The area is well known for its high summer temperatures and moderate winter temperatures.

MAP OF THE FARMS

in the study area north-west of Otjiiwarongo, Namibia



Woody plant composition with large *A. luederitzii* trees as observed on a farm during the survey.

Woody Species

A total of 30 woody species (bushes and shrubs) were recorded in the survey of the woody plants and they were broadly divided into three groups:

Scarce and/or desirable species not to be targeted for removal/harvesting

Potentially problematic species that may thicken under specific conditions, but with a low biomass potential

Potentially problematic species that may thicken under specific conditions and which have a high biomass potential

BROAD CLASSIFICATION OF WOODY SPECIES

based on desirability, potential to thicken and biomass potential

GROUP 1 Scarce and/or desirable species	GROUP 2 Potential problematic species – low biomass	GROUP 3 Potential problematic species – high biomass
Acacia erioloba	*Grewia flava*	*Acacia erubescens*
Boscia albitrunca	*Grewia flavescens*	*Acacia fleckii*
Boscia foetida	*Grewia retinervis*	*A. hebelacada subsp. hebeclada*
Ehretia alba	*Grewia villosa*	*Acacia luederitzii*
Commiphora pyracanthoides	*Lycium spp.*	*Acacia mellifera subsp. mellifera*
Maerua parvifolia	*Catophractes alexandri*	*Acacia reficiens*
Philenoptera nelsii	*Rhigozum brevispinosum*	*Acacia senegal*
Ziziphus mucronata	*Phaeoptilum spinosum*	*A. tortilis subsp. heteracantha*
	Tarchonanthus camphoratus	*Dicrostachys cinerea*
	Terminalia prunoides	*Combretum apiculatum*
		Terminalia sericea

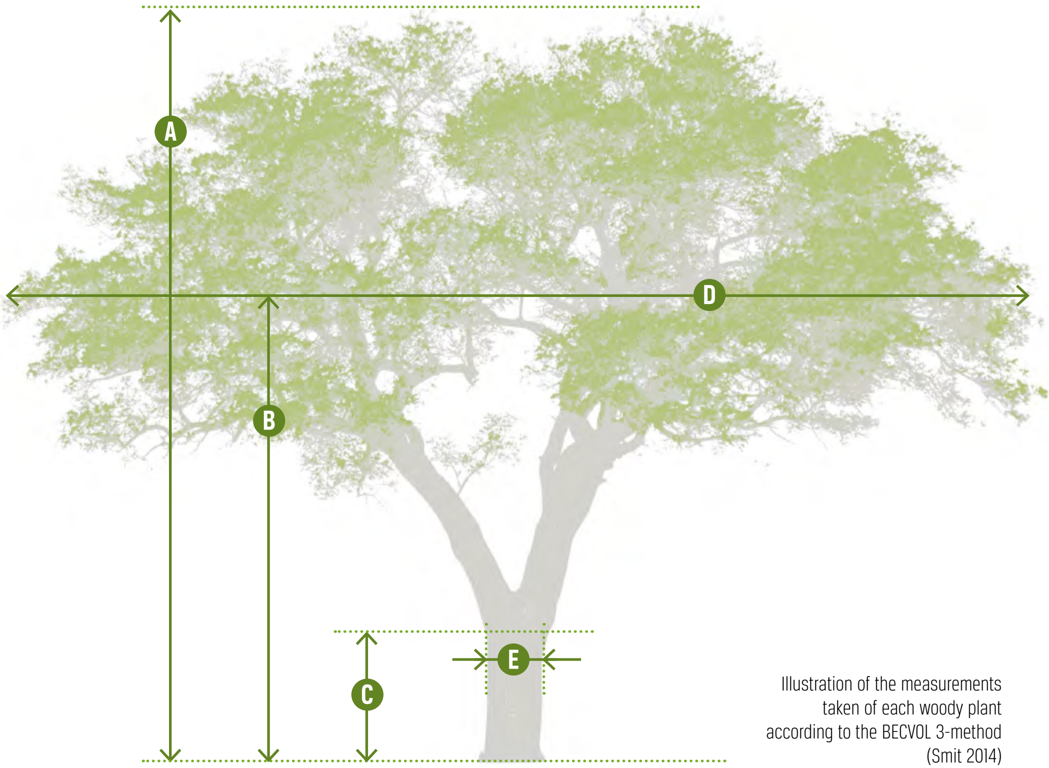


Illustration of the measurements taken of each woody plant according to the BECVOL 3-method (Smit 2014)

Measurements

At each identified survey site a belt transect of 50 to 100 x 2.5 m (125 to 250 m2) was laid out in such a way as to best represent the woody vegetation of that site. The dimensions of all rooted, live woody plants (bushes and shrubs) >0.5 m in height were measured in the various belt transects according to the BECVOL 3 procedure. These measurements include the following:

- **A –** Maximum bush height
- **B –** Height where the maximum canopy diameter occurs
- **C –** Height of first leaves or potential leaf bearing stems
- **D –** Maximum canopy diameter
- **E –** Base diameter of the foliage or stem at the height of the first leaves

Values of Biomass

Values that were calculated with the BECVOL 3-model are:

- Bush density (plants/ha)
- Evapotranspiration Tree Equivalents (ETTE/ha)
- Leaf biomass (kg DM/ha)
- Shoot dry mass - shoots <0.5 cm (kg DM/ha),
- Stem dry mass - stems >0.5-2.0 cm in diameter (kg DM/ha),
- Wood dry mass - wood >2.0 cm in diameter,
- Total wood dry mass (all fractions) (kg DM/ha), and
- Total bush biomass - leaves and wood combined (kg DM/ha)

Assessment Criteria

Taking into account the ecological implications of bushes in savannahs, the following four aspects are considered the most important from an agro-ecological point of view:

- Competition with herbaceous vegetation for soil water and nutrients
- Soil enrichment and creation of sub-habitats suitable for desirable grass species
- Food for browser and mixed-feeder herbivores (livestock, as well as wildlife)
- Source of energy (firewood, charcoal, biofuel and other potential uses such as electricity generation)

Add to this the important issue of "ecological services" of woody plants in terms of carbon sequestration and it is clear that the negative consequences of bush thickening are only part of a much bigger picture. An appropriate conceptual model of vegetation dynamics is also an important prerequisite for effective and predictive management of Namibian rangelands.

an Evapotranspiration Tree Equivalent (ETTE) is defined as the leaf volume equivalent of a 1.5 m single-stemmed woody plant

An example of a belt transect (50 – 100 × 2.5 m) demarcated by a tape measure and 2.5 m measuring pole.

Measurements taken of all rooted woody plants (bushes and shrubs >0.5 m) in the belt transects of 50 – 100 × 2.5 m of each plot for analysis with the BECVOL 3-model.

DISCUSSING DENSITY

The leaf volume of bushes and bushes (ETTE) determines their competitiveness with grass

The ideal number of bushes to be retained can be derived by comparing leaf volume and rainfall, but should not be seen as a fixed number

Besides leaf volume, also bush densities need to be considered

In order to assess the severity of the bush thickening, the calculated bush densities (plants/ha) and ETTE/ha of the survey plots were used as the main criteria. The question regarding the ideal number of bushes that should be retained is complex and is influenced by many considerations. The aridity of the area needs to be borne in mind since more woody plants can be retained in wet than in dry areas without affecting herbaceous yields. In general, the average long term rainfall is a deciding factor. A "general rule of thumb" stipulates that the median number of ETTE/ha that can be supported in a specific rainfall region without adversely affecting the grass layer, should not exceed 10 × the mean annual rainfall. The reason why it is called a "general rule of thumb" is because it is not intended or even suggested to be an exact value. It is not possible to define such a value. Since the rainfall varies from season to season the bush density (in terms of ETTE/ha) at which bushes negatively compete with grasses will vary from season to season. This value is thus used as a guideline only and should not be considered fixed or non-negotiable. The value of this approach is that it provided a reference point that had already been used in other areas, which makes comparisons possible. If we assume a mean annual rainfall of 457 mm for the study area, this "general rule of thumb" implies a target figure of approximately 4 500 ETTE/ha. Anything above this figure presents a possible problem in terms of negative grass-bush competition.

Selective thinning of woody plants will not only reduce competition between the bush and the grass layer, but also among the remaining bushes. This will result in increased growth of the remaining bushes until they reach another state of equilibrium where the bush growth will stagnate due to inter-bush competition. This is generally a desirable effect since this will also increase the area in which new bush seedlings will be suppressed by the larger bushes. To allow for this expected increased growth of the remaining bushes and to maximise the wood harvest, it may thus be justified to thin the woody plants to a density below 4 500 ETTE/ha. In this case, it can be reduced to 60 per cent of the theoretical maximum allowable ETTE/ha, which is calculated at approximately 2 700 ETTE/ha. The 60 per cent is based on the research findings that showed that the mean canopy diameter of bushes increased 38 per cent after selective bush thinning. However, it must be noted that the suggestion of the 2 700 ETTE/ha is not absolute. It merely serves as an alternative reference for a less conservative approach to bush harvesting.

At this level of thinning/harvesting the remaining bushes will initially provide insufficient competition to prevent woody plants from regenerating in the cleared area. Follow-up measures will be required to prevent this from happening.

A situation may present itself where the absolute ETTE/ha value is below the critical value of 4 500, but the bush density is very high. Based on the mean equivalent ETTE-values of woody plants within the 2.0-3.0m height class, the bush density of plants should not exceed 600 plants/ha. If the bush density exceeds this number, but the ETTE/ha value is below 4 500 ETTE/ha, it is often due to a large number of very small plants, which is also undesirable.

Contrast between rangeland with regular bush control (left) and untreated area (right).

Take Away Messages

- **Re-thickening of woody plants after the initial bush control is the single biggest reason why so many attempts at solving the problem in Namibia have failed.**
- **Key to successful implementation of wood harvesting and restoration of bush thickened areas is to consider both the negative and positive aspects of the bushes in their specific savannah ecosystems.**
- **It must be considered how ecological processes within the total ecosystem will be influenced by drastic measures such as harvesting.**
- **Any bush harvesting programme that also includes restoration of thickened areas as an objective should prioritise selective harvesting rather than total harvesting of all woody plants.**
- **Through selective thinning of woody plants a stable and productive state of the ecosystem can be obtained**

Observations from the field visit to Otjiwarongo

Otjiwarongo and its surrounding farmlands are among the areas most affected by dense bush thickening. The experiences of farmers who have conducted bush control measures showcase the complexity of the topic.

During the field visit to the study area in the Otjiwarongo district, the generally poor condition of the rangelands mainly due to bush thickening was very obvious. The desperate situation was aggravated by a below average rainfall of 300 mm of the previous season. During discussions with various farm owners three aspects became apparent:

- The problem of bush thickening has now reached such a critical point that it threatens the continuation of profitable cattle farming in the area
- The cost of bush control measures is a major obstacle, especially in view of the low return on capital that is typical of extensive cattle farming
- Re-thickening of areas previously treated (mechanical, chemical or a combination of both) is a reality and a major problem

Complex Causes and Solutions

These comments did not come as a surprise and support the realisation that the causes of bush thickening, as well as the solutions to the problem are far more complex than generally anticipated. The simple approach of pursuing the most cost effective and quickest method of killing as many woody plants as possible is not always in the best interest of long-term solutions, and in many cases aggravated the problem almost beyond restoration. In general, the farmers were well informed and aware of the potential pitfalls and requirements of maintaining an open savannah, but more often than not they simply do not have the resources to apply the required measures. Having said this, the research team also noted less effective measures that may not have been the most appropriate under the circumstances. These observations are valuable since they provide an opportunity to learn from the successes and also from the mistakes

Learning from Success Stories – and from Failures

Previous and ongoing efforts of individual farmers to combat bush thickening provide important insights. It is evident that bush control is a continuous effort and not a once-off activity.

Aerial Applications of Arboricides

The active chemical ingredients of the most common arboricides sold in Namibia are Tebuthiuron and Bromacil and they can be applied selectively by manually applying them to the roots of target plants. Alternatively, they can be applied from the air in a non-selective manner over large areas. After application they remain inactive on the soil surface until rain carries the active ingredient into the soil where it is taken up by the bush roots, thereby inhibiting photosynthesis so that the leaves yellow and abscise and new leaves that are formed also abscise. This process continues until the bush no longer has reserves to initiate regrowth and dies.

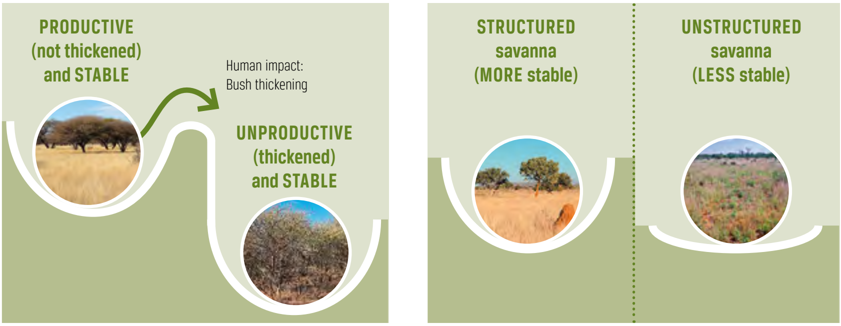
Several examples of non-selective aerial applications of arboricides (mostly Tebuthiuron) were observed in the study area of which some were fairly recently done. The normal outcome of these non-selective aerial applications is mortality of plants of a large number of species and size classes. A few species such as *Boscia albitrunca* are fairly resistant to Tebuthiuron and survive.

Example of an area where an arboricide (tebuthiuron) was aerially applied and is now invaded by *Grewia flava* that appears to be the first woody species able to overcome the residual tebuthiuron remaining in the soil.

Example of a stand of dead bushes after the aerial application of a non-selective arboricide.

SAVANNA STRUCTURE

Illustration of a simplified approach to the principle of stability, resilience and domain of attraction as applied to bush encroachment, illustrating the importance of savanna structure (preserving large bushes).



Natural savannah ecosystems always tend to return to a point of relative stability (equilibrium). A dense bush thickened area represents a very stable environment. Killing some or all the woody plants in such a stable environment creates a vacuum that needs to be filled with other plants. In applying this type of treatment it is hoped that this vacuum will be filled with grasses rather than other plants. In many cases this is indeed the case in the short-term, but unfortunately without further management this is seldom a permanent condition/state.

Grasses are fast growing and respond very quickly to the removal of competition for soil water from the woody plants, as well as to the massive amounts of nutrients that are released from decaying roots of the dead plants. In time, with diminishing nutrients, combined with grazing, this vacuum may again become increasingly populated by woody plants. Due to the limited distribution of the roots of seedlings and saplings of woody plants in the soil they often survive the initial application of the aerially applied

Stability: Natural defences against the rapid re-establishment of woody plants are a healthy and strongly competitive grass layer, and the protection of large woody plants that are able to suppress the establishment and survival of new bush seedlings.

Instability: Areas virtually cleared of all woody plants can only be kept open by a constant (almost annual) follow-up action to avoid re-establishment of woody plants.

An example of a **STRUCTURED SAVANNAH** with a productive grass layer and enough woody plants to ensure the benefit of woody plants such as soil enrichment, food for browsers and increased stability through suppression of bush seedlings.

arboricide and when the mature plants are killed, they flourish.

Potential invasive woody species are usually present in the environment as a natural component. These species are encouraged by disturbances where they act as pioneers and are able to colonise disturbed areas very rapidly, forming dominant stands, while excluding other more desirable species. A classic example of this is *Grewia flava* that appears to be the first woody species able to overcome the residual Tebuthiuron that remains in the soil after an aerial application. It uses this ability to invade the open areas between the surviving *Boscia albitrunca* bushes at the expense of other woody species and grasses. If left untreated the situation will develop in a state that is worse than before the treatment. The cost of a major follow-up treatment may equal or exceed the cost of the original treatment, with the result that these areas are often discarded to become unproductive rangeland.

In some cases non-woody and non-grass plants species such as forbs may colonise disturbed areas. These forbs are almost without exception unpalatable, while still competing negatively with the grasses. The biggest risk of the use of these non-selective arboricides in aerial applications is that the effect cannot be reversed in the short- or medium-term. Large woody plants that may be more than 50 years old and which are able to stabilize the environment by suppressing seedlings and saplings in their near vicinity are killed, leaving behind an unstable environment that needs to be constantly battled to prevent re-infestation, often at considerable expense. Another disadvantage of this approach is that the dead bushes remain standing for a long time and do not seem to break down and decay like bushes that died of natural causes. The implication thereof is that the dead bushes need to be physically removed, which adds to the cost factor.

Mechanised clearing of bush using a bulldozer resulting in top soil disturbance.

Charcoal produced from Namibian encroacher bush.

Mechanical Treatments

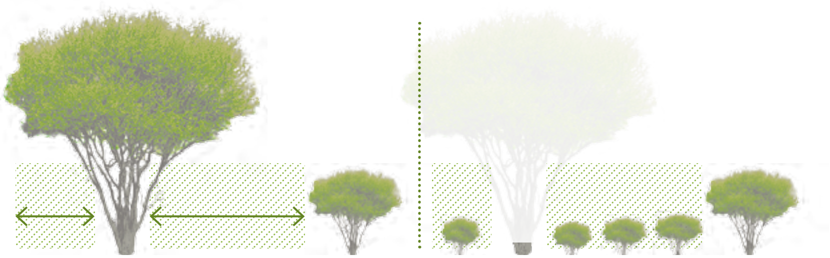
Mechanical clearing is usually undertaken with a heavy implement such as a bulldozer blade, which may also remove some of the roots of the bushes. In cases where a heavy roller is used, the woody plants are often crushed, but not killed. Coppice regrowth from the collar region of woody plants is well documented and is likely to occur. Severe soil disturbance may often encourage the establishment of large numbers of seedlings of some woody plants such as *Dichrostachys cinerea* which has hard scaled seeds that can survive for long periods in the soil, just waiting for the right opportunity to germinate en masse and grow.

Livestock and wildlife can also act as dispersal agents by consuming the seed pods and dispersing the seeds in their dung. In time this may result in a woody community which is denser than the original community. Thus, such mechanical methods are not generally recommended and should rather be avoided.

Harvesting for Charcoal Production

Presently, charcoal and firewood production are the main source of income from excessive woody biomass on agricultural land in Namibia. Only wood thicker than 2.0 cm is suitable for this purpose. In principle, land owners are not allowed to harvest woody plants indiscriminately. They must apply for a permit, which is issued by the Directorate of Forestry (MAWF) and is valid for 3 months. This permit contains strict measures which harvesters must adhere to, i.e. no stems harvested should have a diameter of more than 15 cm. Though these rules are generally accepted and supported by farmers, the reality is that they are difficult to enforce. Since workers are paid according to the weight of the wood they harvest, the incentive to cut large woody plants to maximise income is the main reason why more often than not large bushes and trees are being cut.

SAVANNA STRUCTURE



Bush-on-bush competition appears to be species specific and a positive correlation between the size of a bush and the distance to its nearest neighbour was reported. This implies that large bushes are able to suppress the re-establishment and survival of new bush seedlings (left) and if a large bush is removed it will be replaced by a large number of seedlings (right).

The smaller bushes with thin stems (low biomass) should primarily be targeted during bush control measures and some of the larger bushes be retained, however, the opposite tends to happen in areas where woody plants are harvested for charcoal production. The consequence of this is that although a short-term income is being generated, it contributes very little to solving the bush thickening problem. In fact, areas where larger bushes were selectively harvested for charcoal production have now been invaded by low biomass species such as *Grewia flava* and *G. flavescens* that form very dense, almost impenetrable, bush clumps with no benefit in terms of increased grass production. It is also unlikely that the woody biomass of these areas will ever again be suitable for charcoal production due to species composition and structure.

Aftercare Programme Essential

As explained, removal of some or all of the woody plants creates a vacuum that will invariably be re-populated by woody plants, sometimes by more aggressive species. Natural defences against this phenomenon which have been documented and which can be utilised, include a healthy and strongly competitive grass layer, and large bushes that are able to suppress the re-establishment and survival of new bush seedlings.

An area where bushes were selectively harvested for charcoal production and which has since been invaded by *Grewia flava* and *G. flavescens* that form very dense, almost impenetrable, bush clumps.

Despite these natural allies in the fight against re-infestation of aggressive woody species, an aftercare programme is absolutely essential to keep a thinned area open. This can be done in several ways such as mechanical slashing of new seedlings, localised (selective) chemical treatments of new growth, or even applying less popular management options such as controlled burning in combination with browsers. An efficient grazing management system that will ensure the maintenance of a healthy grass layer is also essential.

➜ **Natural defences against the rapid re-establishment of woody plants are a healthy and strongly competitive grass layer and the protection of large bushes that are able to suppress the establishment and survival of new bush seedlings.**

A disturbed area invaded by *Pechuel-Loeschea leubnitziae* (Wild sage or Stink bush).

An area virtually cleared of all woody plants, kept open by a constant follow-up action to avoid re-establishment of woody plants

The most important aspect of an aftercare programme is that it should not be viewed as a once-off operation, but should become a permanent component of the day-to-day management of the farm. Prior to any thinning/harvesting operation, careful consideration should be given to this aspect and it is essential that the cost implications of such an aftercare programme be realised and budgeted for. In general, the higher the intensity of thinning/clearing, the more aggressive the potential re-invasion and the more frequently actions need to be taken to keep such an area open.

Areas subjected to a high intensity of clearing can be kept open and productive with a regular (almost annual) aftercare programme to control the re-establishment of woody plants. Annual cutting of the grasses for hay will also assist in controlling new bush seedlings. Areas where the grass *Cenchrus cilliaris* is established can be considered a field/planted pasture and no longer a rangeland with natural grazing and should be managed accordingly. From the interviews with landowners it is clear that many farmers understand the need of an aftercare programme, but few of them apply effective aftercare programmes because of the high costs involved.

Bush Harvesting for Biomass Utilisation

For savannah restoration larger bushes should be retained, while economically viable harvesting requires a certain minimum biomass harvest per hectare. In practice it will be necessary to make compromises.

Large Bushes for Stable Ecosystems

The most responsible ecological approach to wood harvesting should be selective thinning of the excess woody plants if long-term restoration of the rangeland from bush thickening is an important objective. The next question is which bushes should be removed and which bushes should be retained. The answer is clearly that the large bushes (or largest bushes available) should be retained at the cost of smaller bushes and shrubs. The objective should be to reduce the leaf biomass (not wood biomass) of woody plants in affected areas in such a way that the suppressive effect of the woody plants on the grass layer is reduced to increase grass production.

The presence of large bushes, representing a structured savannah, will result in a more stable ecosystem. Such a structured ecosystem can be considered the most productive since all the benefits of woody plants are represented. These benefits include soil enrichment, which is a slow process and thus mainly associated with larger (and thus older) bushes and increased stability as large bushes may suppress the establishment and development of woody seedlings under their canopies and in their close proximity. The latter aspect is very important since it may in time reduce the frequency and cost of aftercare programmes.

Natural defences against the rapid re-establishment of woody plants are a healthy and strongly competitive grass layer, and the protection of large bushes that are able to suppress the establishment and survival of new bush seedlings.

Balancing environmental sustainability and economic viability requires careful preparation of any harvesting operation.

Calculating Compromises

However, restoration of bush thickened areas is not the only objective of this initiative. For the economically viability of biomass harvesting for purposes of electricity generation, a certain minimum biomass harvest per hectare is required. The fact that the highest biomass yields reside in large bushes, while these same bushes are also the bushes that need to be retained, presents a potential conflict of interest. For this reason, a realistic approach to the wood harvesting will invariably have to involve a compromise of harvesting as many bushes as possible, while still retaining the benefits of some remaining bushes. A considerable advantage of harvesting biomass for electricity generation is that all biomass can be utilised, compared to harvesting for charcoal production where only stems thicker than 2.0 cm can be utilised.

The total wood dry mass (all fractions) of the 28 plots varied from a low 7 291 kg/ha to a high of 190 942 kg/ha with an average of 36 222 kg/ha. On average the wood >2.0 cm in diameter made up 70.1 per cent of the total wood mass, while the stems >0.5-2.0 cm and shoots <0.5 cm made up 20.8 and 9.1 per cent of the total

In the study area, an average of 36 t/ha of biomass was found (problematic species only, i.e. groups 2 and 3, compare page 7)

SUMMARY OF THE AVERAGE WOOD AND LEAF DRY MATTER PRODUCTION

HEIGHT CLASS (M)	WOOD DM/PLANT (KG)	LEAF DM/PLANT (KG)	LEAF : WOOD	LEAF %
>0.5 – 1.0	0.229	0.102	1 : 2.245	44.54
>1.0 – 2.0	1.398	0.306	1 : 4.569	21.89
>2.0 – 3.0	4.552	0.830	1 : 5.552	18.01
>3.0 – 4.0	5.504	0.979	1 : 5.622	17.78
>4.0 – 5.0	-	-	-	-
>5.0 – 6.0	-	-	-	-
>6.0	-	-	-	-

Summary of the average wood and leaf dry matter production per plant of bush and shrub of **GROUP 2** (see page 7) as well as the ratio leaves: wood and percentage that the leaves comprised of the total plant biomass

HEIGHT CLASS (M)	WOOD DM/PLANT (KG)	LEAF DM/PLANT (KG)	LEAF : WOOD	LEAF %
>0.5 – 1.0	0.184	0.104	1 : 1.769	56.52
>1.0 – 2.0	0.966	0.317	1 : 3.047	32.82
>2.0 – 3.0	6.557	1.147	1 : 5.716	17.50
>3.0 – 4.0	26.506	2.609	1 : 10.159	9.84
>4.0 – 5.0	60.341	3.909	1 : 15.436	6.78
>5.0 – 6.0	192.816	7.214	1 : 26.728	3.74
>6.0	579.353	11.387	1 : 50.878	1.97

Summary of the average wood and leaf dry matter production per plant of bushes and shrubs of **GROUP 3** (see page 7), as well as the ratio leaves : wood and percentages that the leaves comprised of the total plant biomass

wood mass respectively. Should the bushes be harvested during the summer months when the bushes have their full leaf carriage, the leaves on average would add another 6.8 per cent to the total bush dry mass. It can, however, be expected that most of the leaves will probably be lost during the harvesting and chipping process as they dry and fall from the branches.

From the data it is also clear that a high wood mass per hectare is without exception related to the presence of very large bushes. Wood mass per hectare increased exponentially along an increase in the number of very large bushes, while plots of predominantly small to medium sized bushes – even at very high densities – yielded a much lower wood mass.

From the data of the study it is also evident that the potential woody biomass is extremely variable from area to area. The reason for this is partially due to environmental differences (soil type and depth, topography and drainage lines), but also due to past management activities such as mechanical and chemical bush control measures and wood harvesting for charcoal. This resulted in a mosaic pattern of high variability that complicated the extrapolation of the biomass estimations to larger areas.

Harvesting Scenarios

Ideally the best extrapolation of the data would require the subdivision of the whole study area in grid blocks where each grid block is allocated a biomass value based on the biomass of a comparable survey site. Unfortunately an extensive exercise like this was beyond the objectives, budget and time allocation of the project. Despite the limitation mentioned above it can be deducted that based on the average of 36 222 kg/ha the study area of 45 000 ha carries an estimated wood biomass of 1 629 990 metric tons (1.63 mil. metric tons).

Three possible harvesting scenarios can be considered:

- Total biomass harvest. This is more of a theoretical option than something that should be considered. The purpose thereof is to assess the total biomass resource available in the study area that can also serve as a reference to the selective harvesting options
- Selective harvesting with a conservative target – retaining 4 500 ETTE/ha
- Selective harvesting with an optimistic target – retaining 2 700 ETTE/ha that allows for the increased growth of the remaining bushes

Based on the conservative approach (target of 4 500 ETTE/ha), an average of 10 811 kg/ha wood can be harvested in the study area, which represents approximately 30 per cent of the total wood biomass. Reducing the target to 2 700 ETTE/ha will increase the wood harvest with an additional 1 841 kg/ha to 12 653 kg/ha, which represents approximately 35 per cent of the total wood biomass. The suggestion of harvesting only 30 to 35 per cent of the available wood biomass may seem over conservative, but must be viewed in relation to the unique characteristics of each plot in terms of species composition, density and structure. The harvested wood may in fact vary from as high as 96 per cent of the available wood biomass (disturbed area with a dominance of invasive species of group 2) to a low of 4 per cent (plots with already a low biomass). Some plots with big bushes may render a harvest of up to 53 000 kg/ha, but still at a low percentage (28.1 per cent) of the total wood biomass of that plot. It would appear that even the conservative wood harvesting intensity (4 500 ETTE/ha remaining) will still meet the minimum requirement of 10 000 kg/ha for the viability of an electricity plant.

In the study area, 11-13 tonnes of biomass can be harvested per hectare

AVERAGE WOOD BIOMASS PER HECTARE

	WOOD BIOMASS				
	TOTAL AVAILABLE (kg)	HARVESTABLE WITH 2 700 ETTE TARGET (kg)	% OF TOTAL	HARVESTABLE WITH 4 500 ETTE TARGET (kg)	% OF TOTAL
Averages	36 222	12 652	35	10 811	30

Average wood biomass per hectare available in the study area based on three possible harvesting scenarios.

MEAN EQUIVALENT ETTE/PLANT-VALUES OF ALL WOODY SPECIES COMBINED

HEIGHT CLASS (M)	ETTE/PLANT				
	ALL SPECIES	A. MELLIFERA	A. LUEDERITZII	A. REFICIENS	GREWIA SPP.
>0.5 – 1.0	0.43	0.43	0.64	0.43	0.79
>1.0 – 2.0	1.63	1.90	2.52	1.74	2.21
>2.0 – 3.0	4.58	5.57	5.10	5.13	4.45
>3.0 – 4.0	10.97	11.71	10.52	11.66	5.98
>4.0 – 5.0	16.53	15.97	19.20	19.68	-
>5.0 – 6.0	28.14	29.05	32.90	-	-
>6.0	44.58	53.46	41.63	-	-

Mean equivalent ETTE/plant-values of all *Acacia mellifera*, *A. luederitzii*, *A. reficiens* and *Grewia* species in seven hight classes (all 28 plots combined). See page 9 for definition of ETTE.

Leaves Matter

It is interesting to note that the survey plots with the highest wood biomass were those that have not been treated or harvested in any way in the past. Yet despite their high wood biomass they often score lower in terms of the severity of bush thickening. Other plots with a low harvestable wood biomass may score higher in terms of the severity of bush thickening. When assessing the severity of bush thickening, it is the amount of leaves that matters and not the amount of wood. The reason is that the leaves of the woody plants transpire water and the potential water use of woody plants (and thus competition with grasses) is directly correlated to leaf biomass and not wood biomass.
In addition, large bushes often have well developed root systems and a larger percentage of the water that they access may be sourced from deeper soil layers beyond the rooting zone of the grasses.

In addition, the ratio of leaves to wood, as well as the percentage that the leaves comprise of the total plant, differs considerably between plants of different sizes, and also between species of different growth forms. Small trees and bushes have a high ratio of leaves to wood (1 : 2.245 and 1 : 1.769 respectively for the >0.5 – 1.0 m height class) and the leaves can comprise up to 56 per cent of the total plant biomass. On the opposite end of the scale, very large trees have a very low ratio of leaves to wood (1 : 50.878 for bushes >6.0 m) and the leaves as a percentage of the total plant biomass can be as low as 1.96 per cent. Individual plant species of group 2 (see table page 7) will never achieve a high wood biomass because of their growth form (e.g. *Grewia flava*). The selective harvesting of plants from species group 3 (e.g. Acacia species) may result in their replacement by species from group 2, resulting in a lowering of the biomass production potential of that area, which has also been observed in the study area.

Example of rangeland after bush thinning and regular after care measures.

Aftercare Options

It is recommended that bushes be selectively harvested, starting with the smallest plants and progressively moving to larger plants until the target of retaining 4 500 ETTE/ha or 2 700 ETTE/ha has been reached. Harvesting should concentrate on the potential problem species (species from groups 2 and 3 – see table page 7) whereas non-problem species (species from group 1) should be preserved. If for example only bushes larger than 5 m are retained at a target value of 2 700 ETTE/ha, an average of 90 bushes/ha will remain (since 1 bush >5 m equals approximately 30 ETTE).

A further issue that needs be addressed is whether the harvested plants be treated or allowed to regrow producing another biomass harvest after a number of years. It is suggested that the final decision on this aspect be left to the individual farmer. However, it is important to mention a few important considerations that may assist in the decision:

- The majority of African savannah bushes are able to coppice vigorously after mechanical damage, therefore cutting without treatment with a stem-applied arboricide will result in coppice regrowth.
- A clear distinction must be made between existing plants that have been cut and that will regrow (coppice) from the collar region of the plant, versus new woody plants that will establish from seeds. Both these forms of regeneration are likely to occur after harvesting.
- Coppice regrowth will result in a plant that is structurally different from the original plant (multi-stemmed shrub vs. single-stemmed tree) and may probably never render the same wood biomass as the original plant. Because photosynthesis takes place in green leaves they are the factories of the plants, and after damage they will always prioritise the replacement of leaf biomass and not the replacement of wood biomass. It has been shown that bushes that are cut and not treated will regrow to their original leaf biomass within five years, but with significantly lower wood biomass. They

The majority of African savannah bushes are able to coppice vigorously after mechanical damage and cutting without treatment with a stem applied arboricide will result in coppice regrowth.

may continue to grow to a point where the leaf biomass (and thus competition with the grass layer) exceeds the original leaf biomass, while still having a much lower wood biomass.

- The species composition of the woody plants after bush harvesting is likely to differ from what it used to be before the harvesting. Aggressive species such as *Dichrostachys cinerea*, *Grewia* species and *Catophractes alexandri* may invade and in time compete more severely with the grass layer, while producing less wood to harvest.

Where the decision is taken to treat the stumps of the harvested bushes, it must be done with an ecologically safe arboricide as soon as possible after cutting without risk to the remaining bushes. The soil applied arboricides (Tebuthurion and Bromasil) are not recommended because of their non-selective nature and they are also unsuitable for bushes that were cut. Provision must be made for a follow-up treatment the next season to control coppice growth of plants not properly treated the first time. An effective and continual aftercare programme needs to be implemented to prevent/reduce the re-establishment and possible infestation of undesirable woody plants (re-thickening).

Dichrostachys cinerea

Catophractes alexandri

Example of coppice regrowth of untreated plants after harvesting.

Where the decision is taken to allow the stumps to regrow for purposes of producing another biomass harvest after a number of years, it is recommended that an aftercare programme still be implemented. For this purpose the re-establishment and possible infestation of undesirable group 2 species (low biomass species) should be controlled. Where possible, the number of stems of multi-stemmed coppice regrowth should be reduced to encourage the development of thicker stems that will produce biomass similar to the original harvested plants. The approach will also benefit the establishment of grasses during the interim period up to the next harvest

Bromacil is the active ingredient of arboricides commonly sold and used in Namibia.

Views of Key Stakeholders

A total of 15 key stakeholders were interviewed, including full-time commercial farmers, representatives of the Charcoal Producers Association, Namibia Agricultural Union (NAU), Namibia National Farmers Union (NNFU), Ohorongo Cement Factory, Directorate of Forestry (MAWF).

... on value addition

In terms of the impact of bush thickening, farmers admitted that they have reached an irreversible situation where even the best rangeland management practices will not result in the restoration of the rangeland. Financially, farmers are not in a position to spend more money on efforts to counter the adverse impact of bush thickening. The only solution would be to pursue a win-win strategy where the farmers and the environment will benefit by viable long-term solutions. In general, the news of the envisaged power station that utilises the biomass of locally harvested woody plants, was favourably received and for many it presented new hope for overcoming the devastating effect of bush thickening. The Namibia National Farmers Union as well as the Namibia Agricultural Union is in strong support of this project, provided that it is done in an environmentally responsible way.

... on bush control

Most of the farmers applied at some stage one or more methods being recommended for combating bush thickening. These included the use of a variety of arboricides (aerial spraying, foliar, stem absorbent and soil applied arboricides). Initial success in terms of increased grass production following the mortality of the woody plants was reported by these farmers, but because of the removal of competition, new seedlings established themselves, while undesired smaller bushes filled the created vacuums. Because labour intensive methods like felling and stumping are believed to be too time consuming and too expensive, they are not considered viable options. In addition, the farmers have not experienced positive results with certain mechanical bush removal methods (bulldozing, bush rollers) either, since re-infestation was more severe and the areas were in a worse condition than before within only a few years after treatment.


1

... on biomass supply

According to the experience of farmers, it will take in the order of 10 to 15 years for re-growth to produce the same amount of biomass as before harvesting. Currently Namibia is facing serious challenges in terms of future electricity supply. All people interviewed are confident that there is more than enough biomass in the country for running several biomass power stations of 20 MW on a sustainable basis.


2


3

PICTURES

1
The Gerus electricity substation north-west of Otjiwarongo.

2
Mechanical removal of a woody plant with heavy machinery.

3
Processed biomass from encroacher bush.

Conclusions

The study results show that there is sufficient biomass for electricity generation in the study area. Clear priorities need to be identified prior to the harvesting operation and realistic targets set.

Sufficient Biomass for Electricity Generation

Based on the average measured wood biomass available on the commercial farms in the close proximity of the Gerus electricity substation north-west of Otjiwarongo, the planned harvesting of biomass of indigenous woody plants for electricity generation that requires a minimum of 10 000 kg harvestable wood DM/ha appears to be ecologically viable.

Based on the assumption that a 20 MW biomass power plant requires 150 000 tons biomass per annum and that such a power plant will have a life span of at least 15 years, it will require 2 250 000 tons biomass over this time period. Using the two proposed harvesting scenarios (leaving 4 500 ETTE/ha and 2 700 ETTE/ha, respectively) will require a total area of approximately 178 000 ha (leaving 2 700 ETTE/ha) to approximately 208 000 ha (leaving 4 500 ETTE/ha) to supply the required biomass to the power plant over this time period. This represents an area 3.9 to 4.6 times that of the study area (45 000 ha).

Research on Regrowth Required

This calculation, however, does not include the biomass of possible follow-up harvests of areas that were previously harvested and where the bushes were allowed to regrow. The assumption by some farmers that the bushes will regrow to their original biomass prior to the harvesting in 10 to 15 years may be over optimistic. There is a general lack of scientific information on regrowth rates of woody plants, but based on what is currently known it is unlikely that harvested plots will regrowth to their original biomass in this time period, unless the harvested areas are specifically managed to encourage regrowth of woody species from group 3 (high biomass species), rather than group 2 (low biomass species). This aspect should be a priority for further research.

If the presented guidelines are followed, a viable balance between environmental sustainability and economic viability of bush utilisation can be achieved.

Clear Priorities are Essential

Based on the massive amount of biomass that is required for a 20 MW biomass power plant, it is clear to see that the incentive to harvest more bushes than is ecologically desirable is a definitive reality. For this reason, clear priorities need to be identified prior to the harvesting operation and realistic targets set. Responsibility and accountability are essential to avoid exploitation of natural resources for short-term financial gain at the cost of long-term sustainability.

Continual Aftercare

It should also be realised that the harvesting cannot be considered a once-off operation. A continual aftercare programme will need to be implemented following the harvesting, regardless of whether the stumps of the harvested plants are treated with an arboricide or allowed to regrow for purposes of producing another biomass harvest after a number of years.

Resolving Logistics and Financing

The successful implementation of the project will largely depend on resolving challenges of logistics and financial constraints (cost of harvesting, chipping and transport and remuneration of farmers for harvested woody plants). Co-operation between all role players need to be obtained and training on all levels will be essential.

Imprint

Commissioned by:

Support to De-Bushing Project
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Published: 2015

Authors:
Prof G.N. Smit (Dept. of Animal, Wildlife and Grassland Sciences, University of the Free State, Bloemfontein, South Africa)
J.N. de Klerk (Windhoek, Namibia)
M.B. Schneider (DRFN-Desert Research Foundation of Namibia, Windhoek, Namibia)
J. van Eck (Windhoek, Namibia).

Edit: Ina Neuberger
Design & Layout: Martin Markstein, www.dermarkstein.de

Photos: Prof G.N. Smit, except:
pages 11, 16 (left), 21, 25, 29 (bottom): J. Laufs, Support to De-bushing Project
page 26 (bottom left): C.T. Johansson
page 26 (bottom right): Bart Wursten

Print: John Meinert Printing (Pty) Ltd

Support to
De-bushing
Project

Beyond Bush

Many attempts at restoring bush thickened areas are unsuccessful. Results are the loss of beneficial woody plants and re-encroachment, often resulting in a state that is worse than before treatment.

A solution lies in the site-specific quantification and assessment. The authors present a suitable methodology and explain how the bush-grass equilibrium can be restored through targeted bush thinning.

They reason that it is crucial to maintain larger bushes in order to prevent the rapid re-thickening by more aggressive and invasive woody species.

A pilot assessment was conducted surveying 45 000 hectares of farmland close to Otjiwarongo. An enormous amount of 36 tonnes of biomass per hectare was found and the authors suggest that one third of this biomass can be harvested in an environmentally sustainable manner.