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THE POTENTIAL IMPACTS OF WOOD HARVESTING OF BUSH THICKENING SPECIES ON BIODIVERSITY AND ECOLOGICAL PROCESSES*

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ABSTRACT

Studies of the effects of bush clearing have mostly focussed on economic issues such as production. In this paper, biodiversity and ecological effects of bush clearing were investigated, largely through a literature survey. Vertebrate and plant taxa were focussed upon. Two future scenarios were discussed. The first scenario was that future wood harvesting would follow Forestry Stewardship Council Principles and Forestry Guidelines. The second scenario was that demand exceeded supply and that sound sustainable principles would be abandoned in certain areas, in order to chase demand. In the first scenario, biodiversity would be improved, as would ecological processes. In the second scenario, arboreal species, including cavity users, and species requiring microhabitats and shelter would be badly affected, with local extinctions of these species likely. Management recommendations are provided. Biodiversity research should be viewed as a priority, in order to better understand the effects of different wood harvesting management strategies.

INTRODUCTION

Bush thickening is considered to be partially a result of mismanagement of the land, with overgrazing and reduced movement of cattle being considered to be the main management causes. Other factors such as soil, rainfall, fire regime, browsing pressure, the presence or absence of megaherbivores, frost and other disturbances also play a role in determining the dynamics and the competition between woody species and the herbaceous layer in savannas. Bush thickening has resulted in significantly lower grazing carrying capacities throughout rangeland in Namibia, and most likely a reduction in biodiversity, although this has not been measured. Bush thickening is considered to be a relatively recent phenomenon in Namibia, however, Anderson (1856), an early explorer, also recorded high densities of bush in his travels through the land, around 150 years ago, and there is considerable debate as to the origins of the current bush encroachment problem.

Recently, charcoal production has been promoted as a cost effective way of clearing unwanted bush. Charcoal is sold locally, regionally and internationally. Plans are currently underway to build a silicon smelter which would require approximately 125 000 tons of wood to produce charcoal for the reduction of silicon oxide to silicon. Other smelting industries may follow. The USA has recently approached the Namibian government regarding importing charcoal. A recent report (Stewart Scott Namibia Consulting Engineers, 1999) advocated the use of wood for the generation of electricity. It estimated that, for two power plants proposed, 275 000 tons would be needed (the idea has apparently been shelved for economic reasons). There is concern that, at some point, with the escalating demand envisaged, wood harvesting will become unsustainable and affect biodiversity conservation and ecological processes negatively. The potential cumulative impacts of these developments need to be assessed. Currently, research has focused mainly on the impacts of bush encroachment on agricultural production. This paper provides a preliminary and crude assessment of the potential effects bush clearing may have on biodiversity and ecological processes, as well as management, monitoring and research recommendations.

THE AREA AFFECTED BY BUSH THICKENING IN NAMIBIA FROM A BIODIVERSITY PERSPECTIVE

The area affected by bush encroachment and thus likely to show an increase in wood harvesting in Namibia is estimated to be about 260 000 km^2 (based on Bester (1999) for commercial areas and Zimmermann and Joubert (*in prep.*) for communal areas). This bush thickened area affects parts of at least seven vegetation types in Namibia, namely Mopane Savanna, Mountain Savanna and Thornveld, Thornbush Savanna, Highland Savanna, Camelthorn Savanna, Forest Savanna and Woodland (Giess, 1971). The bush-thickened areas fall mainly within the semi-arid savannas with rainfall varying from about 300 mm in the west to about 500 mm in the north-eastern parts.

In some areas, a wide variety of game species can be found, and, in the Thornbush Savanna, the highest density of cheetahs in the world occurs, despite persecution by farmers. A centre of high endemism for plants, reptiles and birds lies on the western edge of this bush thickened area (Barnard, 1998). Nine out of the fourteen endemic birds found in Namibia occur in the affected area (Barnard, 1998). These are Hartlaub's francolin, Rüppel's parrot, Rosyfaced lovebird, Violet woodhoopoe, Monteiro's hornbill, Carp's tit, Barecheeked babbler, Rockrunner and White-tailed shrike. These are mainly associated with the endemic rich western escarpment, but occur towards the east of the affected area as well. None are completely restricted to the affected area. The Herero chat is represented by only a small single population of about 110 000 (Barnard, 1998). This population, is however, situated mainly west of the affected area.

PROCEDURES

In this paper impacts of bush clearing and wood harvesting are discussed for two extreme management scenarios:

a. Wood harvesting that is based on approved Forestry Stewardship Council (FSC) guidelines, as is currently the case with farmers who are supplying Jumbo Charcoal. In this scenario, we look at the potential impacts of wood harvesting, where operators have due regard for biophysical environmental considerations.

b. Wood harvesting in which FSC principles are abandoned due to demand exceeding available supply. This scenario may arise if there are too few farmers willing to consider wood harvesting under FSC restrictions, while the demand elsewhere is high. This is considered to be a worst-case scenario.

The potential impacts were determined during an environmental impact assessment conducted for a proposed silicon smelter in 2000. Literature was consulted to determine the potential ecological impacts, which endemic vertebrate species occurred in the area and what the habitat requirements of certain species were. This was then related to the two scenarios outlined above. Farmers opinions were obtained through questionnaires and interviews (see Zimmermann and Joubert, *in prep.*)

CURRENT FSC PRINCIPLES

In order to sell charcoal to Europe, FSC certification is required. In order to obtain certification, certain requirements, pertaining to economic, social and environmental sustainability, must be adhered to. Farmers need to adopt a management plan which can be periodically updated and can be checked by FSC officials. The FSC principles are covered in the recommendations section in this paper. These have in fact largely corresponded to the guidelines suggested by Piepmeyer (1996). In brief, farmers adopting FSC principles in Namibia follow these environmental guidelines. Each farmer has, however, leeway to follow his/her own management plan, provided that FSC principles are met.

Each farmer, working within the principles, harvests according to his/her management plans (to improve grass production; to improve visibility for game viewing, etc.). For example, some of the farmers interviewed are currently only harvesting dead wood.

DISCUSSION

Grass production and quality

It is not within the scope of this paper to comprehensively summarise the extensive literature available on this topic in southern Africa. The few examples below illustrate typical research results and current thinking.

Most studies in southern Africa have shown substantial increases in grass productivity with the complete or almost complete removal of trees, yet a number of studies show a higher grass production at low densities rather than zero densities of trees (Stuart-Hill, Tainton and Barnard, 1987; Teague and Smit, 1992). They ascribe the increase in grass production partially to competitive release, as well as to the release of locked up nutrients in decaying wood. In the case of wood removal for wood harvesting however, the latter reason would only partially apply in the short term with the discarding of finer wood material and leaf matter after harvesting. The removal of wood would result in a long term overall nutrient loss from the soil, since the nutrients locked up in the wood would be removed along with the wood. Furthermore, many of the species to be utilised (*Acacia* species, *Dichrostachys cinerea*) form nodules for nitrogen fixation, and there would thus likely be a further reduction in soil nitrogen levels with the removal of these species, unless herbaceous legumes are able to compensate. Stuart-Hill *et al.* (1987) have shown that *Acacia karoo* trees in the Eastern Cape, South Africa, facilitate the growth of grass, due to increased shade and leaf litter. They conclude that, at low tree densities, the competitive effects of trees are more than compensated for by the facilitative effects. It is likely that this is generally applicable to all savannas, including Namibia's semi-arid savannas.

In the Namibian context, similar results to studies elsewhere have been obtained, although there is not much published information. For example, at Vergenoeg, in Omaheke Region, the grass production in an area harvested for firewood two years previously, was found to be more than double than in the adjacent uncleared area (Uazukuani, 2000).

All farmers interviewed experienced higher yields after bush clearing. However, some have warned of the likelihood of reduced yields with total clearing. Grass production appears to be dependent upon the size of trees more than the total cover. Areas with larger single or few stemmed trees seem to generally have a higher grass production than areas with many smaller multi-stemmed bushes, regardless of the cover. The thinning of trees and the subsequent pruning will increase grass production substantially, according to current thinking. Excessive thinning (almost complete removal) may result in higher yields in the short term, but there would then be a risk of increased erosion, especially immediately after harvesting. Also, there is a possibility of resprouting individuals reducing grass production in the long term. Although trees are less effective cover against rainsplash erosion than grass, if there is little grass cover present at the time of harvesting, rainsplash erosion will be increased, resulting in annual xerophytic grasses with low forage value and low cover predominating. Also, shade-loving species, such as *Panicum maximum*, which has a high yield, will disappear.

Results concerning grass production are fairly unequivocal, the general trend being an increase in grass production with a decrease in tree density and cover up to a limit. The converse seems to apply to grass quality. The higher nutrient status under trees (Scholes and Walker, 1993) is likely to lead to a higher nutrient quality of grasses under a tree canopy. Once more, most research has shown this, in one form or another (Tainton, 1999). Also, some species, such as *Panicum maximum*, a very good quality, high yielding grass, is particularly associated with larger trees (*pers obs*). Large-scale total clearing of an area would result in the loss of this and other shade-loving species and a decline in grass quality in general after the initial release of nutrients has subsided.

Tree thinning is likely to improve grass forage quality, but almost total clearing will substantially lower this.

Browse production

Obviously, the complete removal of trees in an area would reduce the browse to zero, at least in the short term. The value of reserve browse, even for cattle, in times of drought, has been commented on by a number of people, and many communal farmers rely heavily on this when grazing is scarce. The thinning of bush may result in the remaining trees growing more rapidly, or the increased establishment of new individuals since *Acacia* species fail to establish under canopies (Teague and Smit, 1992). This can be attributed to competitive release.

It has also been found that leaves are shed later in winter as a result of thinning (DFN, 1997). This has the added benefit of improving the survival chances of browsers such as kudu through the bottleneck period occurring in the dry season (DFN, 1997). The removal of browseable shrubs may to some extent indirectly reduce available browse, due to the remaining trees growing more rapidly beyond the browse line for medium sized browsers such as kudu. Bester and Van Eck (1998) have found that, in the Thornbush Savanna (Giess, 1971), kudu favoured *Lonchocarpus nelsii*, *Boscia albitrunca*, *Boscia foetida* and *Maeura* and *Grewia* species (all broad-leaved species) over the generally much commoner microphyllous species (which include many of the bush thickening species). The thinning of these thickening species should allow an increase in productivity of the remaining more palatable broad-leaved species. At one of the farms in the Hochfeld district, an area in which harvesting had occurred two years ago, had a significantly higher cover of small palatable species such as *Grewia flava* (see Zimmermann and Joubert, *in prep*).

Smit and Rethman (1998) have found improved flowering and fruiting rates with thinning of *Colophospermum mopane*. This is likely to apply to other bush thickening species, also as a result of competitive release. Trees remaining are thus likely to increase seed banks in the soil over time, the germination of these replacing at least some of the removed trees.

Thinning is likely to improve the browse available for browsers, and have positive effects on the population dynamics of the tree species themselves. Total clearing would result in no browse initially, but this would change gradually as seedlings germinate and chopped trees resprout.

Plant species and structural diversity

Both herbaceous and woody species diversity is likely to be increased by thinning under FSC guidelines, since the dominance of the thickening species will be reduced, allowing other species to thrive. Also, if all size classes of trees are represented, and patches of dense bush are left, structural diversity will be increased, both vertically (different sized trees) and horizontally (open grassy areas and patches of dense bushes). This, in turn will promote species diversity, since more niches will be created. In the worst case scenario, the total removal of trees and bushes will reduce structural diversity and thus niches defined by structure, or the total removal of thickening species, will reduce niches defined by species or genus specific associations.

Faunal species diversity: game species

The thinning of bush thickened areas is very likely to result in a shift in the proportions of game species. Populations of species requiring browse or dense cover for predator evasion (kudu, giraffe, eland, Damara dik-dik, duiker and steenbok) are likely to decline, unless some dense patches are maintained. Plains species and grazers (e.g. blue wildebeest, zebra, warthog, oryx and red hartebeest), which rely on fleet footedness in evading predators, may be favoured (DFN, 1997). Complete, or almost complete removal of trees will effectively reduce the carrying capacity of the area in question, since the browse component will be absent. Game species diversity would decrease.

The thinning of trees under FSC guidelines, with some smaller patches of dense bush remaining for predator evasion, will favour most game species. Worst-case scenario total clearing will reduce game species diversity through the exclusion of bush loving species.

Cheetahs would be advantaged by tree thinning, partially because of their preference for open habitat, but also as a secondary impact of the increase in prey diversity. This may be offset by the increase in conflicts with farmers, resulting in more cheetahs being shot. Roan and sable would be favoured by the removal of most trees, provided grass cover remained high for the concealment of calves.

Faunal species diversity: game birds

There are six species of francolin (Crested, Coqui, Swainson’s, Orange River, Hartlaub’s and Red-billed) and one species of Guinea Fowl (Helmeted) in the general area considered for harvesting. Of these, only the Orange River Francolin may be favoured by the complete, or almost complete, removal of trees. The others, including the endemic Hartlaub’s Francolin, all require either some tree cover or patches of dense bush for cover from predators. Thinning of trees, with the inclusion of patches of dense bush, should maintain healthy populations of these species. Excessive, or complete, removal of bush will lead to the local extinction of these species, if cleared areas are extensive. Game bird hunting is rapidly becoming an economically important form of tourism in South Africa and so this has some economic bearing for diversifying agricultural economies.

Faunal species diversity: game species: other bird, small mammal and reptile species

141 species of birds, which have been recorded in a ¼ degree square near Otjiwarongo, nest in forks of branches (Gibbons and Maclean, 1997). Approximately 44 species of birds nest in cavities in trees in the affected area (Gibbons and Maclean, 1997). The thinning of bush can have two contrasting effects. Excessive removal of trees will reduce nesting space for both branch fork and cavity nesters. However, moderate thinning of bush, and the subsequent pruning of regrowth under FSC guidelines, should favour these species, as trees released from competitive inhibition will grow taller and have thicker stem diameters more suitable for cavity users. Certain tree species, such as *Boscia albitrunca* and *Acacia erioloba*, have gnarled and twisted stems that form natural cavities favoured by hornbill species. Some species of birds may favour impenetrable shrub for nesting, as this may afford them some protection. Marico Flycatchers have been observed nesting in small multi-stemmed *A. mellifera* shrubs at around 1 m, despite the presence of larger single or few stemmed trees nearby (*pers obs*.).

Many small mammals, for example small spotted genets, Egyptian free tailed bats, Cape serotine bats, South African lesser bushbabies and black-tailed tree rats also use cavities for shelter and breeding, whilst woodland mice nest in trees (Skinner and Smithers, 1990).

Large dead trees are particularly important habitats for the cavity users mentioned above.

Large scale clearing as envisaged in the worst case scenario would have major impacts on arboreal reptiles, those reptiles dependent upon natural bush for cover from predators, thermoregulation, and reptiles dependent upon the microclimatic conditions and litter beneath trees and shrubs (M. Griffin, *pers comm.*). Some genera that might be negatively affected include some *Mabuya* and many lacertid genera such as *Nucras* and *Ichnotropis* (M. Griffin, *pers comm.*).

Large scale clearing would especially disadvantage reptiles and small mammals, since their dispersal abilities are limited. Small populations widely dispersed may act in isolation and may thus not be viable.

The above examples serve to illustrate the importance of trees as habitat for smaller vertebrates that are often overlooked. There are many species that prefer open grassy plains to thickets. However, the thinning under FSC guidelines should accommodate their preferences adequately.

The diversity of habitats which thinning, in combination with patches of dense bushes provide, will also have a positive knock on the effect along trophic chains: the increased diversity of prey will result in an increased diversity of predators.

Thinning of bush will have a positive effect on Cape Griffons, if they are reintroduced to Namibia, as has been recently proposed. Cape Griffons have the highest wing loading of all southern African vultures (Mundy *et al.*, 1992). This means that they require a long "run way" to take off after eating. The bush cover in the affected areas does not allow for this, and, in fact, bush encroachment has been cited as one of the major reasons for the functional extinction of Cape Griffons in Namibia, along with poisoning by farmers. Wood harvesters who have "vulture restaurants" on their property can clear a few small areas of around half a hectare each to act as "runways" for these vultures.

The trends for reptiles and invertebrates are likely to be the same as for small mammals and birds. Complete thinning will eliminate the arboreal niches, whilst thinning, pruning and the maintenance of patches will increase habitat heterogeneity and thus increase species diversity. There should always be representatives of all woody species, since there are many species (or genus) specific associations. For example, the larva of the Western Marbled Emperor moth (*Heniocha dyops*) is dependent upon *Acacia mellifera*, *Acacia erubescens* and *Acacia hereroensis* for its food supply (Oberprieler, 1995).

Soil surface

The impact of bush clearing on soil surface characteristics is dependent upon a number of factors. Most importantly, if rainfall occurs in a bush cleared area soon after clearing, soil capping is likely to result, especially in heavier textured soils, since there is no protection from rain-splash impact. This could secondarily result in soil erosion and also lower grass yields, since less water is penetrating the soil. Kennard and Walker (1973, cited in DFN, 1997) recorded higher infiltration rates beneath trees than in the open. However, if a good grass cover results (which literature indicates is most likely), soil surface characteristics tend to improve, since grass is a more effective barrier against rain-splash erosion (Matthee and Van Schalkwyk, 1984). Complete removal of the tree layer will possibly result in increased erosion if overgrazing or fire removes the grass layer. If leaves and twigs not suitable for wood harvesting are left on the soil, this will act as mulch, and also increase the production of grasses and hence improve the protection of the soil surface.

Water table

The impact of bush clearing on the water table is dependent upon a number of factors, including the extent of clearing. Trees reduce the rainsplash impact of raindrops by intercepting raindrops and thus slowing their velocity. As already mentioned, the grass layer, being closer to the ground is more effective in reducing rainsplash impact. Infiltration may be either reduced or increased. Total clearing of trees will increase the risk of capping, erosion and hence reduce ground water recharge. Woody plants are major users of soil moisture (Scholes, 1998, cited in DFN, 1997), and *Acacia mellifera*, in particular, has a very high transpiration rate (64. 8 kg/plant/day for a 2.5 m plant) (Donaldson, 1967). Water table levels are likely to increase in the short term, with wood harvesting, but this is likely to be temporary, as increased grass cover will intercept water in the topsoil, thus reducing infiltration to the water table.

Soil fertility

Bush clearing initially increases the availability of organic material (twigs and leaves for decomposition) and thus increases the mineralisation process. This leads to an increase of nutrients, previously locked up in wood. However, there must be a net loss of nutrients from the system, since wood (and hence potential nutrients) are removed, and not replaced in any other way. Furthermore, *Acacia* species, and *Dichrostachys cinerea* are likely to harbour nitrogen-fixing *Rhizobium* bacteria in root nodules. If these species are removed, the input of nitrogen is likely to be reduced. There are however a number of leguminous herbs which could continue this role and these might increase as a result of reduced nitrogen levels in the system. The overall loss of nitrogen from reduced nitrogen fixation is difficult to determine.

Table 1, based on figures of different nutrients' concentrations for *Burkea africana* wood in a broad-leaved savanna at Nylsvley in South Africa, shows approximately how much of each nutrient will be lost from the system, assuming one harvesting in a 20 year period. This figure would obviously increase after reharvesting.

Scenario 1 was based on figures obtained from interviews with a charcoal producing farmer and Jumbo Charcoal. The movement of nitrogen from the system may be partially compensated for by nitrogen fixation. It is also possible that nitrogen fixation may increase since legumes tend to predominate on nitrogen poorer soils. The loss of other nutrients such as phosphorous and the cations represents a longer-term net loss from the system.

Another potential increase in nutrient loss may secondarily result from an increase in the incidence of grass fires due to increased grass production and thus increased fuel loads. Nitrogen loss is due to the volatilisation and pyrodenitrification of ammonia, nitrogen gas and nitrous oxide during a fire (Scholes and Walker, 1993). Phosphorous and sulphur are similarly lost to the atmosphere. The biophysical significance of this is probably negligible, since fire is a natural process in savannas.

Complete clearing, as well as thinning under FSC guidelines to a lesser extent, will result in an overall nutrient loss from the system. The overall significance of this is, at this stage, difficult to determine.

Table 1. Approximate nutrient losses (kg) per hectare for different nutrients expected for harvesting; 1. Thinning as proposed in Jumbo Charcoal's guidelines (FSC scenario), 2. By complete clearing in a Worst Case Scenario. These figures are based on the Nylsvley Savanna Study in South Africa (Scholes and Walker, 1993) and were measured in a broad leaf savanna, and thus serve merely as approximations. Nutrient loss as a percentage of the system is given in parenthesis for nitrogen and phosphorous.

Nutrient loss (kg/ha) → **Scenario ↓**	**Nitrogen**	**Phosphorous**	**Sulphur**	**Calcium***	**Magnesium**	**Potassium**	**Sodium ***
1. FSC scenario	83 (2.5 %)	4 (0.5 %)	2	152	3	5	1
2. Worst case scenario	414 (12 %)	21 (2.3 %)	10	760	15	25	4

All values are for *Burkea africana* wood except * (mixed barks and twigs). Figures provided for anions were averaged for the year, whereas those for the cations, are for midsummer.

1. FSC scenario: 10 000 kg of various species per hectare harvested.
2. Worst case scenario: 50 000 kg of *C. mopane* per hectare harvested.

<u>Landscape level processes</u>

DFN (1997) states that macroclimatic changes are only likely for woodland management on a regional scale (thousands of square kilometres). In this case, woodland management *could* eventually be carried out on such a scale. At this stage, it is difficult to suggest what impacts this may have, but may reduce the likelihood of rainfall, due to the increased advection from warmer soils, if complete clearing of large areas occurs. Increased light levels and wind speeds from clearing will also subject animals to greater temperature extremes. The thinning under FSC guidelines, combined with patches of dense bush will minimise the chances of adverse micro- and macro-meteorological changes occurring.

SUMMARY

It is clear that a balance of small and large trees should remain after thinning, since each have their own ecological role. Taller and thicker stemmed trees support shade tolerant fodder grasses, cavity using birds, small mammals and other animals, larger nesting species; whereas smaller shrubs are more available for medium sized and smaller browsing game, and soil is protected from the effects of overgrazing and fire. Structural heterogeneity of vegetation in the form of patches is also important. Patches of dense bush are important habitats for predator evasion for a range of animals. It is widely understood that habitat heterogeneity is one of the strongest correlates of species diversity, due to the increase of potential niches it affords. Since a detailed study of the effects of bush thickening, and bush thinning or clearing on biodiversity would require some years, basic ecological principles must be drawn from observations of farmers in the affected areas, as well as our own observations of their farms, for the purposes of this paper. Wood harvesting, following sound environmental guidelines, should overall, have a positive effect on the biophysical environment. Failure to comply with these guidelines will have serious negative consequences for the environment, particularly for biodiversity. Many of the impacts predicted need further investigation.

Secondary human impacts:
Apart from harvesting wood, the increased risk of poaching and fires are possible side effects which deserve some attention.

MANAGEMENT RECOMMENDATIONS

The environmental guidelines drawn from FSC principles and Piepmeyer's guidelines, are, on the whole sound, and are likely to generally impact positively on the biophysical environment. The following revised guidelines are recommended for the protection of biodiversity and ecological processes (these include currently practiced and Piepmeyer's guidelines):

- **Species to avoid (evergreens; broad leaved species; protected species; riverine species):** These form an important part of the browse component and do not have the regenerative capacity to recover as quickly as the more dominant thickening species.

- **Avoid harvesting on sensitive soils**: Some soils, such as sodic and duplex soils, are extremely erosive (Matthee and Van Schalkwyk, 1984). Wood harvesters should determine the sensitivity of the soil in an area before harvesting. At this stage the distribution of sodic soils in the affected environment is not known.

- **Avoid riverine vegetation:** Riverine vegetation forms important habitat for fauna, and the roots stabilise the soil, which otherwise would wash away in flash floods. Harvesting should be done at least 100 m from riverbeds and watercourses.

- **Avoid using heavy machinery:** Wood harvesters might be tempted to use bulldozers to uproot shrubs that are difficult to chop down. This increases the risk of soil erosion by disturbing the soil surface.

- **Leave the fines:** It is not recommended that twigs be compressed to make woodchips, as has been suggested by some, since these twigs improve soil moisture, soil organic matter and increase nutrient levels in soils after mineralisation, which improves grass production and quality.

- **Leave some dead trees:** Leave at least one or two large dead trees per hectare. This increases available cavities for cavity users, and perches for larger birds such as raptors.

- **Patch harvesting should be done to maintain spatial heterogeneity:** This increases niches and thus species diversity. Patches act as refuges for prey species. Elongated patches can also act as corridors for shy animals to cross from one dense patch to another. Patches should be varied in shape. Elongated corridors increase the ecotonal boundary (or "edge" effect), which promotes diversity (DFN, 1997). However, rounded larger patches are also important to ensure that populations of species restricted to dense bush have sufficient habitat. Patches should be close enough to ensure dispersal and contact between subpopulations.

- **Leave representatives in all height classes of all species**: This increases niches and species diversity. Tall trees are more suitable for cavity users, and for bird species with large nests. Tall trees also increase grass production. Smaller trees and bushes are suitable for medium sized browsers and species of birds and other animals that require shelter (for e.g. three-streaked tchagra).

- **After care:** If re-harvesting of resprouts is envisaged, resprouts need to be pruned to limit the number of stems to one to three. This may speed up time to re-harvest, but also increases the availability of potential cavities for cavity users, nesting space and grass production. Branches pruned can be used as browse for game or cattle or simply left on the soil surface to act as mulch.

- **Regular monitoring:** This should be conducted by wood harvesters and verified by the Directorate of Forestry. Some indicator species of ecosystem health would include hornbill species and other cavity users; climax grass species; regrowth of trees; soil conditions [including assessment of erosion and soil capping]. Benchmarks and/or controls should be established as reference points to compare harvested areas with. A rapid expansion of wood production, to meet the future demands, is not likely to be matched by a similar increase in the Directorate of Forestry's staff and vehicles to undertake the necessary verification on the ground. There may be possibilities to apply remote sensing techniques that detect vegetation changes by detecting NDVI (Normalised Difference Vegetation Indices) changes at the start of dry seasons, when grasses are already dry, but bushes are still green. Any sites showing a drastic reduction in NDVI could then be inspected on the ground.

- **Flexibility in management and a switch to alternatives if "thresholds of potential concern" are reached:** "Thresholds of potential concern" are identifiable indicators which, when a change in their number is detected to a certain predetermined level, warrant a management response to address the issue. These need to be identified, perhaps in discussion within the Woodland Management Council. An example could be the sudden decline in sightings of a certain bird species (e.g. Bradfield's Hornbill) which indicates that suitable cavities are in short supply, thus indicating that there are too few representatives of large trees.

- **Identify sustainable alternative sources outside Namibia:** An in-depth study of alternative sources in South Africa (and elsewhere) needs to be undertaken.

- **Other significant users:** All users of wood and charcoal need to take into account that there are other significant users of wood and charcoal. Environmental impact assessments therefore need to take cumulative impacts into consideration.

- **Awareness:** Farmers and other potential wood harvesters need to be made aware of the biodiversity conservation aspect of farming.

RESEARCH RECOMMENDATIONS

The potential for drastic biodiversity changes, with uncontrolled wood harvesting, is clear. A large-scale biodiversity research initiative is required to determine what impacts are happening to specific taxa with different wood harvesting management strategies. This should be planned for the determination of a national management strategy for wood harvesting.

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REFERENCES

ANDERSON, C. J. 1856. Lake Ngami; or, Explorations and Discoveries during four years wanderings in the wilds of South Western Africa. Hurst & Blacket Publishers, London.

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

BESTER, F.V. 1999. Major problem – Bush species and bush densities in Namibia. Agricola. **10:** 1-3.

BESTER, F.V. and J.A.J. VAN ECK.1998. Preferences of the kudu: Spectrum of utilisation in the Thorn Tree Savanna. Agri-info **4**(6): 9-12.

DFN. 1997. Ecological consequences of woodland management, with special reference to Namibia, Consultancy report produced for the Development Fund of Namibia.

DONALDSON, C.H. 1967. Bush encroachment with special reference to the Blackthorn problem of the Molopo area. Unpublished internal report for Department of Agricultural Technical Services, South Africa

GIBBONS, G. and G. MACLEAN. 1997. Robert's multimedia Birds of Southern Africa. Version 2. Southern African Birding cd.

GIESS, W. 1971. A preliminary Vegetation Map of South West Africa. Dinteria **4:** 5-114.

GRIFFIN, M. personal communication. Ministry of Environment and Tourism.

MATTHEE J.F. LA G. and C.J. VAN SCHALKWYK. 1984. A primer on soil conservation. Bulletin no. *399.* Department of Agriculture, Pretoria.

MUNDY, P., D. BUTCHART, J. LEDGER and S. PIPER. 1992. The Vultures of Africa. John Voelcker Bird Book Fund.

OBERPRIELER, R. 1995. The Emperor Moths of Namibia. Ecoguild, Hartebeestporrt, South Africa

PIEPMEYER, W. 1996. Proposed forest utilisation practice. Guidelines attached to harvesting permits issued by the Directorate of Forestry office in Otjiwarongo.

SCHOLES, R.J. and B.H. WALKER. 1993. An African Savanna: synthesis of the Nylsvley Study. Cambridge University Press.

SKINNER, J.D. and R.H.N. SMITHERS. 1990. The Mammals of the Southern African Subregion. University of Pretoria, South Africa.

SMIT G.N. and N.F.G. RETHMAN. 1998. The influence of tree thinning on the reproductive dynamics of *Colophospermum mopane*. S. Afr. J. Bot**. 64:** 25-29.

STEWART SCOTT NAMIBIA CONSULTING ENGINEERS. 1999. Energy from waste: feasibility study on collection, pretreatment and transport aspects. Consultancy report for the Ministry of Mines and Energy, Republic of Namibia.

STUART-HILL, G.C., N.M. TAINTON and H.J. BARNARD. 1987. The influence of *Acacia karoo* trees on grass production in its vicinity. *J.* Grassld. Soc. Sth. Afr..**3(1)**: 19-24.

TAINTON, N.M. (ed.) 1999. Veld Management in South Africa. University of Natal Press, Pietermaritzburg.

TEAGUE, W.R. and G.N. SMIT. 1992. Relations between woody and herbaceous components and the effects of bush clearing in southern African savannas. J. Grassl. Soc. Sth. Afr. **9(2)**: 60-71.

UAZUKUANI, J.U. 2000. Unpublished Polytechnic of Namibia student project.

ZIMMERMANN, I. and D.F. JOUBERT. *In preparation*. A crude quantification of wood that is and can be harvested from bush thickening species in Namibia.

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