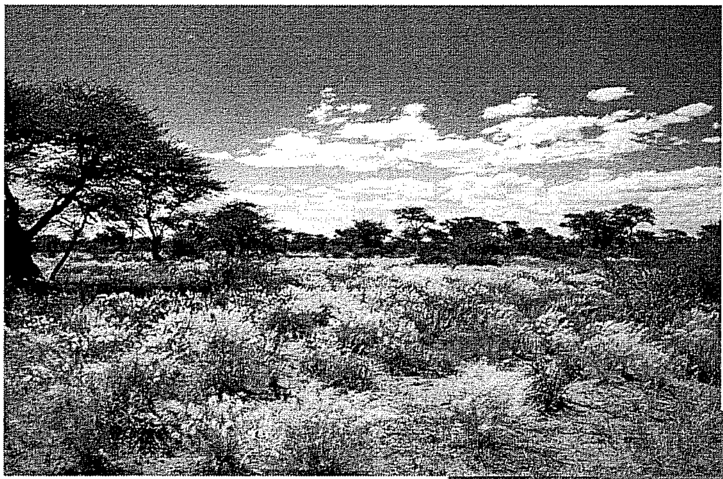
Veld degradation and bush encroachment



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Introduction

Bush encroachment is widespread in Namibia. Currently an estimated 17.5 million ha of commercial farmland is encroached, with shrub densities ranging between 2 000 and 21 400 shrubs per ha (Bester 1998/99). The problem is not limited to Namibia. Reports from South Africa, southern Africa, North Africa, Australia, North America as well as South America all indicate encroachment of woody species in one or other form to be a problem in grazing lands (Donaldson 1969; Donaldson & Kelk 1970; Mostert 1967; Friedel 1987; Schmidt *et al.* 1995; Grouzis & Akpo 1997; Lawton 1967; Pratt & Knight 1970; Prins & Van der Jeugd 1992; Sabiiti & Wein 1988; Schultka & Cornelius 1997; Skarpe 1990; Taylor & Walker 1978; Allegretti *et al.* 1997; Buffington & Herbel 1965; Glending 1952; Glending & Paulsen 1955; Golubov *et al.* 1999; Walker *et al.* 1972 and others).

Bush encroachment is, however, not to be seen as the ultimate problem in grazing management. It is rather part of the natural dynamics of the savanna system. Bush encroachment is a result of certain events and thus a symptom of other problems in the grazing ecology.

Growing strategies of grasses

About 95 % of all Namibian grasses are C_4-photosynthesisers (Ellis *et al.* 1980). The C_4 photosynthesis pathway is different from the common C_3 photosynthesis pathway in that carbon dioxide (CO_2) is actively absorbed even though the stomata are closed due to water stress. This means that C_4 plants are adapted to growing under warm, arid conditions – photosynthesis is taking place at an optimal temperature of 30° to 47° C, whilst C_3 photosynthesis does normally not take place over 30° C (optimum 15° to 25° C) (Salisbury & Ross 1985).

Grasses are well adapted to the erratic climate conditions in arid Africa. Experiments have shown that grasses can utilise small quantities of soil moisture. Even erratic showers of 5 mm are used for growth (Williams *et al.* 1998) – a mid-season drought is by far not as severe for grasses as what it would be for a crop like maize. The dense root mass of a perennial grass also serves to extract the maximum amount of water out of a limited amount of soil (Walter 1954). Especially perennial grasses are thus able to produce some leaf matter under drought conditions (O'Connor 1991a; O'Connor 1994; O'Connor 1995).

The major difference between perennial grasses and annual grasses is that annual grasses can produce seeds within a short period of time (some within a fortnight!), specialising also in producing large numbers of seeds. Little energy is wasted to produce a strong root system or a high leaf mass (e.g. *Aristida adscensionis*). Annual grasses are also very opportunistic, germinating and growing only if enough moisture is available. This means that little or no fodder is produced by annual grasses during dry years.

Similarly, grasses are also well adapted to survive grazing. As a matter of fact it has been proven that many grass species are actively tillering (i.e., producing more productive branches) after light grazing during the growing season (Tainton 1999). However, the balance between stimulating light grazing and actually damaging the plant by heavy grazing is very delicate. Overgrazing during the growing season will lead to reduced photosynthesis and thus overall to reduced growth and production of the grass. The danger also exists that essential meristems (i.e., growth cells) are destroyed by grazing.

However, the combination of heavy grazing and a drought has been proven to be fatal to these perennial grasses (O'Connor 1991a; O'Connor 1995). Thus, a fairly dense perennial grass cover can easily be destroyed by overgrazing combined with drought. After-drought management is of crucial importance: a rest is essential for many of the perennial grasses to survive (Danckwerts & Stuart-Hill 1988).

Different grass species produce different amounts of seeds. O'Connor & Pickett (1992) found that many of the climax grasses producing fairly big seeds produce only few seeds per annum (up to 400 seeds), whilst finer-seeded grasses produce between 1 300 and 4 000 seeds. A comparable pioneer genus, *Aristida*, produced up to 10 000 seeds per annum. Seed production is also reduced if the grasses are grazed during the growing season. Climax grasses show greatly reduced seed production patterns, whilst *Aristida* can maintain a relative prolific seed production under grazing. The availability of seeds is the determining factor in seedling recruitment. The more seeds are available, the more young plants can establish. At the same time, it was also proven that seedling establishment of climax grasses is greatly enhanced if the soil is shaded (O'Connor 1996). Thus, the continuous re-establishment of climax grasses is highly vulnerable to overgrazing.

Degradation gradients

From the above, it is obvious that different grasses react differently to grazing. Originally this was seen as evidence for the Clements succession theory, which described plants as being either climax or pioneer species. In the meantime, however, a distinction has been made between Decreaser, Increaser II, Increaser III and Increaser IV species (see also Figure 1):

- Decreaser species are species present in veld in excellent condition and decrease in abundance when over-utilised.
- Increaser II species are species that occur at a low abundance in veld in good condition, but will increase in abundance when the veld is moderately overgrazed over the long term.
- Increaser III species are species that are rare in veld in excellent condition, but will increase in abundance if veld is heavily overgrazed over the long-term.
- Increaser IV species are rare in veld in excellent condition, but increase when the veld is excessively overgrazed over the long-term. (Vorster 1982)

These trends have been used to develop veld condition assessment techniques. In the Ecological Index Method the relative abundance of the various grasses found in the veld is multiplied with an index value (Decreasers – 10; Increasers II – 7, Increasers III – 4 and Increasers IV – 1) and then summed (Bosch & Gauch 1991; Bosch & Kellner 1991; Hurt & Bosch 1991; Tainton *et al.* 1980; Tainton *et al.* 1978; Trollope *et al.* 1989; Van Rooyen *et al.* 1991; Vorster 1982; du Plessis *et al.* 1998b).

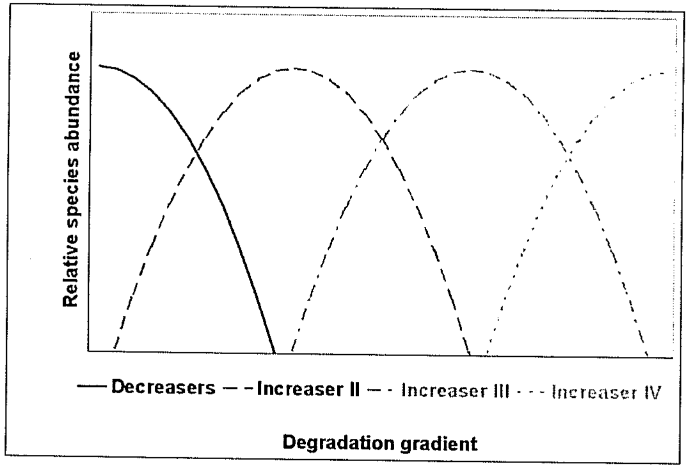

Figure 1. Schematic representation of the reaction of different grass species to a degradation gradient.

The total grass cover will also decrease as degradation progresses, with the various ecological groupings contributing less and less to the cover (Roux & Vorster 1983; Bosch 1989). This is due to the fact that although many of the annual/pioneer type grasses are very abundant, their contribution to the vegetation cover is relatively low. This is also true for their contribution to the available biomass (Figure 2).

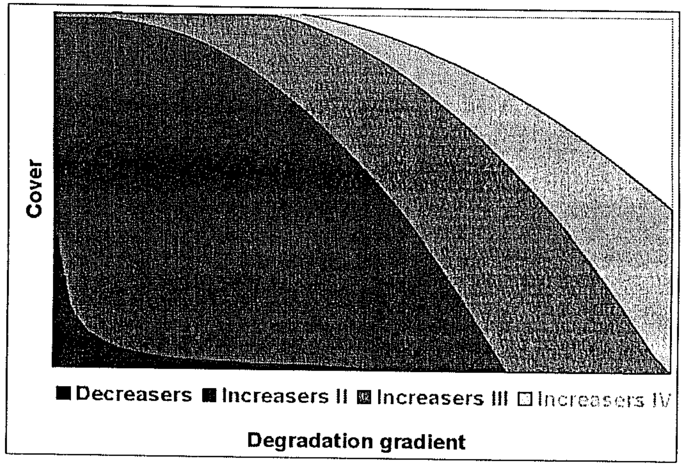

Figure 2. Schematic representation of the change in grass cover over the degradation gradient.

Little data are available on the species reaction of Namibian grasses. Work in this regard has been done in the northern Kalahari in the Grootfontein district (Strohbach 1992), Khomas Hochland in the Windhoek district (Joubert 1997), western Etosha (du Plessis *et al.* 1998a; du Plessis *et al.* 1998b) and in the northern Oshikoto region (Strohbach 2000a; Strohbach 2000b; Strohbach 2000c; Strohbach 2000d).

From these sources a generalised list can be established:

Decreasers:

Anthephora pubescens
Brachiaria nigropedata
Digitaria eriantha
Digitaria seriata
Melinis repens subsp. *repens*
Schmidtia pappophoroides

Increaser II:

Stipagrostis uniplumis var. *uniplumis* (a Decreaser in Etosha!)
Eragrostis nindensis
Aristida meridionalis
Fingerhuthia africana

Increaser III:

Monelytrum luederitzianum
Eragrostis rigidior (a Decreaser in Etosha!)
Urochloa brachyura
Anthephora schinzii

Increaser IV:

Aristida adscensionis
Aristida rhiniochloa
Tragus berteronianus
Tragus racemosus
Eragrostis trichophora
Enneapogon cenchroides
Eragrostis porosa
Eragrostis annulata
Pogonarthria flecki

It must be remembered that this is list a generalised list, and thus not generally applicable. Considerable shifts in species response can be expected especially to the more arid west and south.

Grazing capacity map vs. actual grazing capacity

A grazing capacity map ('drakragkaart') was produced by the then Department of Agriculture Technical Services in the 1970's (Department Landbou Tegniese Dienste 1979). This map has long been regarded as outdated and thus incorrect (Bester 1988a; Strohbach 1995), mainly because it disregarded the fact that grass production is directly dependent on the annual rainfall. Recently collected data elucidate this problem quite clearly.

On a farm in the Okahandja district, the stocking rate has been between 17 to 26 ha per animal since the mid-80's, well below the old stocking rate norm of 14 LSU/ha. However, the failure to destock in drier years, especially the crucial drought in the 1994/95 and 1995/96 rainy seasons, led to a complete breakdown of the carrying capacity of the farm (Figure 3). An attempt was made to restock after the relatively good rains of 1996/97, but the animal numbers had again to be reduced drastically. Indications are that two Decreaser species are locally extinct on the farm (Strohbach & Sheuyange 1999).

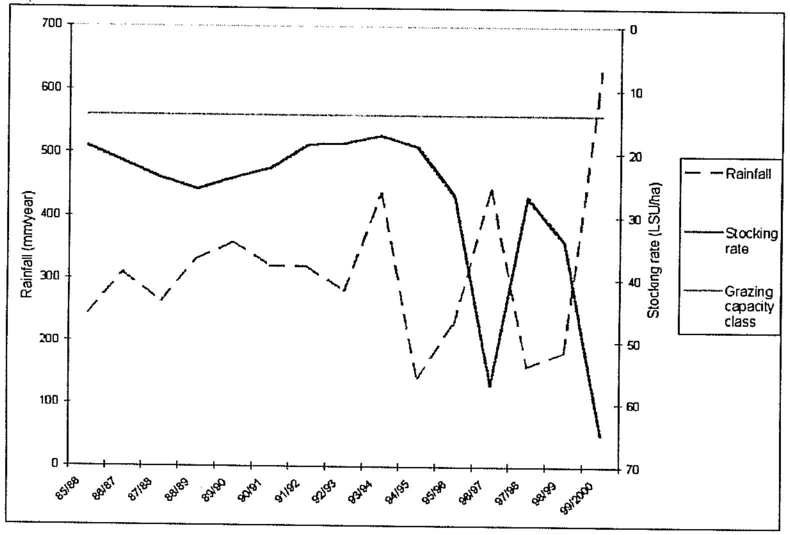

Figure 3. Stocking rate compared to the annual rainfall on a farm in the Okahandja district. Note the complete breakdown of the carrying capacity of the farm in the 1996/97 growing season.

Growing strategies of shrubs

Trees and shrubs are longer-lived plants with a higher biomass. They are not necessary better biomass producers in terms of water use efficiency or sunlight use efficiency, but do have certain competitive advantages over grasses.

Whereas grasses have a relatively small, but very dense root system, trees and shrubs have an expansive, often deep, but not very dense root system (Walter 1954; Timberlake & Calvert 1993). The advantage is that trees and shrubs can extract water from a fairly large soil volume – measurements indicated up to 9m from the trunk of *Acacia karroo* trees of 2.1 m and higher (Stuart-Hill & Tainton 1989), whilst grasses are limited to a small volume of soil. Grasses

thus need a fairly moist soil (e.g. after a rain shower) to grow, whilst woody plants can extract water from a larger volume of soil also during the dry season (Walter 1954; Tainton 1999).

Especially the Mimosidae (e.g. *Acacia* species and *Dichrostachys*) are known as nitrogen fixers. Schulze *et al.* 1991 have proven that *Acacia mellifera* subsp. *detinens* shrubs (common blackthorn) fixed up to 71 % of their structural nitrogen in root nodules. The species *Acacia hereroensis* (mountain thorn) and *Dichrostachys cinerea* (sicklebush) fix up to 49 % structural nitrogen. Although not surplus nitrogen fixators, these species will contribute considerably to available nitrogen to other plants by way of their litter (e.g. deciduous leaves, etc.). Other trees and shrubs like for example *Boscia albitrunca* (shepherds tree) are not able to fix their own nitrogen and have to rely on soil nutrients for this essential component. This is compensated for by being intrinsic slow growers, i.e., their growth rate will never exceed the availability of resources. Through their relatively deep and spreading root systems trees and shrubs can access soil nutrients in deeper soil layers and, through litter, make these nutrients again available to the grasses which have to rely on the upper layers (Walter 1954).

The trunk (or stem) of a woody plant has two functions. It holds up the canopy in such a way that the leaves are best exposed to sunlight and out of reach of browsing animals, whilst it transports water and nutrients between the roots and the canopy (Tainton 1999). Two types of vessels are used for the transport (Fahn 1982).

The *xylem* transports water from the roots to the canopy. This tissue is formed by a ring of cells, the cambium. As these cambial cells divide, the inward growing cells become xylem cells as part of the "sapwood". As these cells become older, they harden and form the dark heartwood in the centre of the stem.

The cambium also divides to the outside. These cells become the *phloem* – those vessels transporting nutrients and biosynthesis-products like sugars etc. between the various organs as well as to the roots of the plants. As the phloem cells become older and dysfunctional, they become the bark of the stem.

Trees and shrubs are particularly sensitive to the interruption of the phloem – it is as if the phloem forms the aorta of the plants. By simply ringbarking a tree (i.e., removing a strip of bark right around the stem) you can effectively kill it (Noel 1968; Teague & Killilea 1990). This also explains the success of fire-girdling ("stambrand") trees and shrubs (Strohbach 1998/99 a & b).

Trees protect themselves against fire by (a) producing a thick bark, thus insulating the phloem below. This has been observed in field experiments that bigger trees, if not burned long enough, would not die (Strohbach 1998/99a). Trees, mainly by shading the area below their canopy, but also through direct competition and allelopathic effects, also prevent a dense growth of grass near their trunk. This explains the fact that very few trees and shrubs actually die during a veld fire, and that a hot fire is needed for a successful burn (Trollope 1980; Trollope 1974; Trollope & Tainton 1986)

Walter's two-layer theory of bush encroachment

It is generally accepted that although numerous factors contribute to bush encroachment, the primary cause is a disturbance of the competitive balance for especially soil moisture between grasses and woody plants (Smit *et al.* 1996). This was already suggested by Walter in 1954 (see also Walter 1971) and is also supported by Knoop & Walker (1985) and Walker *et al.* (1981).

According to Walter (1954), savannas, being grasslands with scattered trees and shrubs, are a result of the delicate balance in the use of available soil moisture. Grasses are highly effective users of water, being able to take up a large portion of the available soil moisture. Very little moisture is thus left for trees and shrubs. Seedlings of especially woody plants have difficulty to establish. The trees and shrubs do not form a dense, closed canopy, thus allowing light to reach the ground (needed for the grasses to grow). Furthermore, these woody plants are also fairly resistant to fire. In contrast, in temperate zones grasslands and woodlands are separated due to the fact that woodlands are highly susceptible to fire, whilst also having such a dense foliage cover that grasses cannot grow under the canopy due to a lack of light.

Cattle (and many game species in central Namibia) are grazers, meaning that they feed predominantly on grasses. On a cattle farm this leads to the possible over-exploitation of this layer of the vegetation, with a general under-utilisation of the woody component of the vegetation. A reduction of the grass sward alone (by grazing) leads to an increased growth rate of trees and shrubs (Stuart-Hill & Tainton 1989; Aucamp 1990). Overgrazing not only leads to a decrease in the sward cover, but also in a change in the composition of the grass layer (veld degradation) and thus a reduced biomass production and water use efficiency of the sward.

In short: a dense stand of grasses, being fast growers and very efficient energy converters, is able to take up and utilise most of the rainwater as it seeps into the ground. Thus, very little water actually reaches the soil layers where woody plants have their roots (Figure 4).

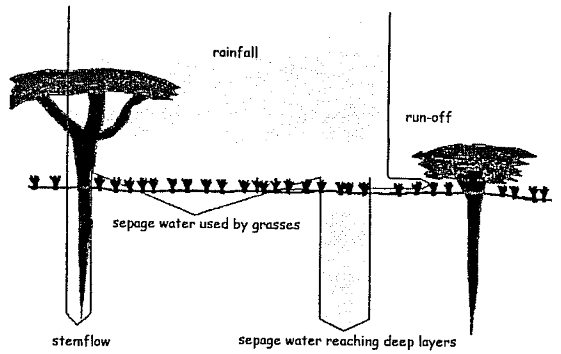

Figure 4. Rainfall distribution in a savanna with a dense grass sward in good condition.

As soon as the grass cover is reduced, two things happen:

i. Less water is used by the grasses, so more of the infiltrating water reaches the deeper soil layers and thus the roots of the woody plants. These then can establish and grow faster (Figure 5).

ii. Decreased plant cover, especially grass cover, will lead to increased soil erosion and soil compaction, in itself leading also to more run-off (Stocking 1988; Lal 1994; Strohbach 2000e). This leads to a reduced ability of grass seedlings to establish (O'Connor 1991b; O'Connor 1996), leading again to a further reduction in the grass cover.

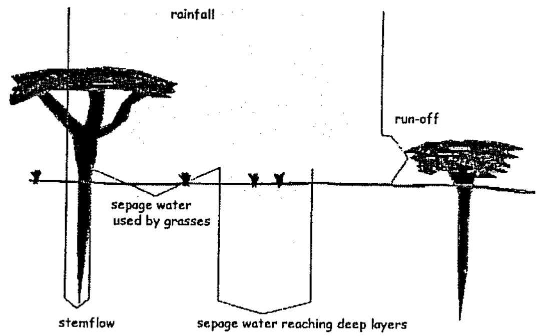

Figure 5. Rainfall distribution in a savanna with an open grass sward in poor condition.

Trees and shrubs are generally not affected by the reduced infiltration rate after the initial establishment boost. This is due to the stem-flow effect - they collect water in their branches and funnel this along the trunk into the soil and through channelling right down to their root level (Pressland 1973; Martinez-Meza & Whitford 1996; Whitford *et al.* 1997). This leads to a fairly arid topsoil, whilst the woody plants are basically self-sufficient in terms of soil moisture (Figure 6).

The savanna system is resilient only to a limited degree in terms of this disturbance in the balance between the woody and the herbaceous component. If a critical amount of shrubs have established and/or the grass cover reduced beyond a critical minimum amount, the system will become unstable and permanently change to a different system dominated by the woody component (Walker *et al.* 1981). This change is then seen as a change in the *domain of attraction* as described by Holling (1973), Walker (1980) as well as Bosch (1989) (see also Strohbach 1990 for an overview) (Figure 7).

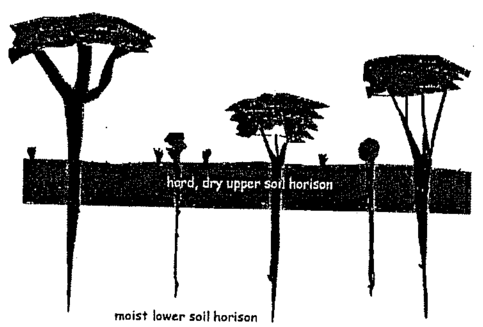

Figure 6. Soil moisture conditions in an encroached savanna.

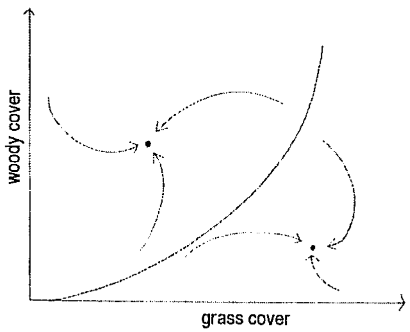

Figure 7. A hypothetical two-variable system with two stable equilibrium points (domains of attraction) (adapted from Walker 1980).

Soil erosion

A review of soil erosion in Namibia, with emphasis on causing factors of soil erosion, has recently been published (Strohbach 2000e).

In terms of veld degradation, the following issues / factors need to be considered:

- Soil is primarily protected by a dense vegetative cover. If the vegetation cover is reduced due to overgrazing, soil erosion will increase.
- Soil erosion is associated with soil capping or crusting. This condition prevents especially grass seedlings to establish, leading to a further reduction in vegetative cover.
- Soil capping or crusting is often associated with clay bubbling (Volk & Geyger 1970). This condition prevents infiltration of water into the soil, thus aridifying the soil further.

- Erosion depletes soil nutrients (which are in any case scarce in most Namibian soils).
- A reduced vegetative cover leads to heating up of the soil, and this to increased loss of especially nitrogen from the upper soil layers through volatilisation. Less nitrogen will also be fixed by cyanobacteria in the upper soil layers if these are hotter and more arid (Schlesinger *et al.* 1990; Cross & Schlesinger 1999).

Conclusion: Factors to consider when removing bush

- **Know your veld**
  Know what signs to look for: how to recognise erosion, overgrazing, etc. Know your sensitive soils and those plant communities that are easily damaged. Bester (1988b) gave a good overview of the signs to look out for. Know the species occurring in your veld.

- **Monitor changes in the veld**
  Make yourself a monitoring plot. A standard plot is about 20x50 m in size. Determine the species composition, especially the tree, shrub and grass composition in this plot. Tree and shrub abundancies can easily be determined by physically counting the individual plants. Normally the plants are grouped into height classes, e.g. below 1 m, between 1 and 2 m, between 2 and 5 m, and above 5 m.

  The relative abundance of the grasses can easily be determined with the 'step-point method' (Mentis 1981): Pace through the plot. At every 2^{nd} step (e.g. the right foot), determine the nearest (grass)plant in front of the toe. Repeat at least 100 times, if possible 200 times. Calculate the veld condition using the Ecological Index Method, by multiplying Decreaser abundancies with 10, Increaser II abundancies with 7, Increaser III abundancies with 4 and Increaser IV abundancies with 1. Sum these values and compare with the previous years' results (or the results of other plots) to see how the veld is developing.

  Repeat these monitoring activities at least annually.

  You can camp off a 50x20 m plot (thus permanently spare it). Use such a fenced off area as control to your veld. If you are debushing, leave a small patch as is (i.e., don't debush it). Compare how your cleared area is developing compared to the originally encroached area.

- **Determine your grazing capacity annually**
  In order to prevent overgrazing, it is essential that you annually determine the grazing capacity of your veld after the rainy season. Bester (1988a) suggests to clip the grasses from 40 squares ($1m^2$ iron frame) spread out diagonally across the camp. This should be repeated for every second camp. The harvested grasses are sorted according to palatability, collected in bags, air-dried and weighed to determine the biomass produced. A general guideline is that 60 % of this biomass can be used for fodder. Kruger (1988) elucidates the calculations necessary to determine the number of animals that can be supported from the veld.

- **Don't remove all trees and shrubs**
  Remember that these plants are part of the natural environment and have a function in nature (however obscure it might be). It has been shown that many Acacia's are nitrogen fixers, meaning that they contribute to soil fertility.

As a general rule, it is recommended to remove up to 90 % of all shrubs below 2 m (these are the actual problem); 60 % of shrubs below 5 m and **NO MORE** than 10 % of all trees and shrubs above 5 m.

➢ **Don't burn the brush – use it as soil protection or as fodder**
Don't burn the brush after harvesting the wood. Many see it as a way to get rid of these twigs; to "tidy the camp". However, you are destroying a valuable part of the nutrients.

By scattering the branches you can:

- Prevent further erosion by creating erosion breaks.
- Provide shade to the ground. This will help to conserve soil moisture, assist grass seedlings to establish, and also promote the fixation of nitrogen.
- Provide shelter to grass seedlings – especially against animals looking for something green & juicy to eat.
- Provide the soil with organic material (which is just as rare in Namibian soils – but as important for plants as soil nutrients).
- Provide the soil with a slow-releasing natural fertiliser (in the form of decomposing organic matter).

The dry, scattered branches are not particularly long-lived. *Acacia mellifera* subsp. *detines* branches decompose within a year!

➢ **Try stem-burning and/or ring-barking as an alternative**
Why spend a lot of money to clear large areas with expensive manual labour or as expensive mechanical means like bulldozers? Provide school kids with an opportunity to earn some pocket money and let them apply stem-burning to some of the problem plants during school holidays. Ring barking has not yet been tested here, but results from Zimbabwe (Noel 1968; Teague & Killilea 1990) indicate that this method can definitely be considered.

➢ **Use the shrub branches as fodder**
Especially during dry years, shrub branches can be used – after grinding – as supplementary roughage (Kubirske 1989). The branch material can also be silaged (Woker, personal communication). Aucamp (1990) suggests the use of goats as additional meat producers relying on browse rather than grazing like cattle.

Another example: In the Americas, *Prosopis* was seen as a noxious weed, encroaching like our shrub into grazing lands. That was until somebody realised that the wood is ideal for furniture and other woodcraft. Now grasslands are actually *planted* with *Prosopis* to produce more wood. It is time that we also find innovative and economically viable uses for our wood resources.

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