SOME PRINCIPLES OF SUSTAINABLE RANGELAND MANAGEMENT IN NAMIBIA

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ABSTRACT

Namibia's economy is heavily dependent on agricultural produce, specifically that obtained from extensive livestock ranching on natural rangelands, which require adaptive management. Current management techniques are unsustainable, resulting in landscape-level bush encroachment and costing beef producers N$700 million per year in foregone income. Free-ranging livestock utilise rangeland forage resources highly selectively, so only the most-preferred grass species should serve as indicators of rangeland reaction to grazing. If these species are over-utilised, rangeland condition will deteriorate and animal production will decline.

At stocking rates of up to 45 kg cow mass/ha, savanna grass swards transform towards less-preferred grasses, and bush encroachment also results at higher stocking rates. Indicator grasses need to recover to seed-set before re-grazing. Drought grazing reserves have to be created by deferred grazing, planting of dryland grass pastures and drought-resistant fodder crops, re-seeding with preferred grasses and increasing the herd flexibility. Bush-encroached areas have to be thinned systematically to restore the grass sward, using controlled fires to prevent re-colonisation of invader bush. Only a combination of these techniques will improve Namibia's savanna rangelands and make profitable, extensive livestock production sustainable.

INTRODUCTION

Namibia's economy is heavily dependent on agriculture, which contributes between 5 % and 8 % to the gross national product (GDP) (MAWF, 2006) and provides a livelihood to more than 60 % of the population (Mendelsohn *et al*., 2002). Up to 90 % of agricultural GDP is created by ranching-based animal production (MAWF, 2006). This production is from farming enterprises where animals, whether domestic livestock or wild game, range freely on the natural rangelands that serve as their forage resource, with comparatively little input of money and time (Pagot, 1992). In Namibia, these enterprises include the production of beef, mutton, venison, karakul pelts and game-based ecotourism.

Considerable input of management knowledge is required, especially of adaptive rangeland management, as rangeland condition is greatly influenced by the fickle and harsh climate, stocking rate of animals and the occurrence of drought and fires (Westoby *et al*., 1989; Tainton, 1999). Degradation occurs easily if wrong decisions are made at critical junctures (Rothauge and Joubert, 2002). Improvement in rangeland management will thus contribute directly to ranchers being more successful and staying on their ranches longer.

The most visible form of rangeland degradation in Namibia is bush thickening, also called bush encroachment, on huge tracts of land. The finely balanced grass-to-bush ratio of a savanna has been severely disrupted in a bush-encroached rangeland (Skarpe, 1991). Bush species such as *Acacia mellifera*, *Dichrostachys cinerea*, *Terminalia sericea* and *Colophospermum mopane* are involved, but normally only one of these species dominates in any specific area. Bush thickets may reach densities of 12 000 bush/ha, especially on the more fertile soils of the Thornbush and Karstveld savanna types in north-central Namibia (Bester, 1998).

Rangeland on which the density of bush-equivalents (a 1,5 m high bush) per hectare exceeds twice the average annual rainfall may be considered as bush-encroached (Prof. G.N. Smit, quoted in De Klerk, 2004). At a density of 6 000 bush/ha, access to the encroached rangeland by livestock is limited physically (Espach, 2007). At such high density, the grass-based carrying capacity of the rangeland may be reduced to one-tenth of its original capacity (Adams and Werner, 1990; Bester, 1998).

In Namibia, the grass-based carrying capacity of degraded, bush-encroached rangeland has been reduced by 40 % to 90 %, and more than 60 % of Namibia's savanna rangeland is affected by bush-encroachment (De Klerk, 2004). It costs Namibian ranchers over N$700 million annually in foregone beef production (De Klerk, 2004)! Whereas the majority of the grasses in an intact savanna consist of perennials, most grasses in a bush-encroached savanna are annuals (Scholes, 1997; Rothauge, 2005). Annual grasses are not persistent, therefore less reliable, generally less productive and less nutritious than perennial grasses; thus, animal production on an annual grass sward is less sustainable and the risks are greater.

The reason for the landscape-level degradation of savanna rangelands in Namibia is that adaptive management is not applied to rangeland by ranchers in commercial and communal farming areas. Adaptive management refers mainly to the number of animals on the rangeland (the stocking rate) and the reaction of ranchers to extreme events such as fires and droughts. It is means of countering not only man-made occurrences such as overgrazing, the permanent occupation of the rangeland and provision of drinking water throughout the year, but also problems arising from natural events, such as the requirement for fire control (Rothauge, 2000):

- Overgrazing is caused by too many animals on the land for too long a period of time. It is brought about by fencing off small portions of the rangeland into camps, where animals are kept for longer and apply more grazing pressure than the savanna grass sward can withstand (Owen-Smith and Danckwerts, 1997).
- The provision of drinking water by sinking deep boreholes all over the farm or region enables livestock and wild animals to occupy the savanna throughout the year. Many commercial ranches provide drinking water to their livestock within three kilometres of their grazing grounds. In the natural system of the past, large tracts of Namibia were without surface water for most of the year and so were occupied by large migratory herbivores seasonally only, or only by a limited number of sedentary herbivores (Owen-Smith and Danckwerts, 1997).
- Even during a drought, a rangeland is no longer evacuated by animals, as was the natural rhythm (Owen-Smith and Danckwerts, 1997). Domestic livestock is kept alive on the range by providing bought-in, foreign feed supplies.
- Fire is an ecological factor in a savanna, as it affects woody plants, especially bush recruits (saplings), more than it affects grasses, thus tilting at the grass-to-bush balance (Bond, 1997). The virtually total exclusion of fire in most commercial ranching areas of Namibia has enabled bushes to colonise the landscape without impediment. It has also allowed a build-up of brush and shrub that ignites occasionally, with catastrophic consequences for rangeland and livestock production.

If some of these management actions or events apply long enough, or coincide with each other or with a drought, the rangeland is pushed over a threshold towards a lower level, where it stabilises (Scholes, 1997). The degraded condition is characterised by less-productive and less-nutritious grasses, reduced biodiversity and declining ecological services, such as reduced rainwater infiltration and increased run-off and erosion (Skarpe, 1991). It appears that every level of degradation is more stable and more difficult to reverse. Each lowered level takes more effort, more money and more time than is available in the productive life of a rancher to repair the ecological damage and to rehabilitate the rangeland (Smit *et al.*, 1999).

At some lower level, degradation becomes practically irreversible. This emphasises the need for adaptive, flexible and opportunistic rangeland management of Namibia's savanna ecosystems so that not only they but also Namibia's extensive livestock production (ranching) systems, so important to the country's economy, retain their sustainability. This article points out some basic principles required for the sustainable management of Namibia's semi-arid savannas and whose application will improve the ranchers' prospects of remaining on their ranch.

FIRST PRINCIPLE: KNOW WHICH PLANTS (GRASSES) LIVESTOCK PREFER TO EAT

Most of Namibia's ranching products are obtained from grazing livestock species such as sheep, cattle and ostriches (MAWF, 2006). Goats, also grazers, are of much smaller significance economically although they are very valuable to the impoverished farmers in communal areas. Most wild game species are mixed feeders, utilising both grass and bush. If the rancher knew which plants these animals prefer to eat, he could manipulate the savanna rangeland, consisting of a balance of grass and bush, to contain more of the preferred forage species than of the less- and unpreferred forages.

In the central, northern, eastern and north-eastern savannas of Namibia, all of them based on aeolian Kalahari sands, cattle prefer two perennial grasses, *Anthephora pubescens* and *Schmidtia pappophoroides.* These which can constitute as much as 70 % of their diet (Figure 1) if they are plentiful in the rangeland (Figure 2) (Rothauge, 2006). This shows that

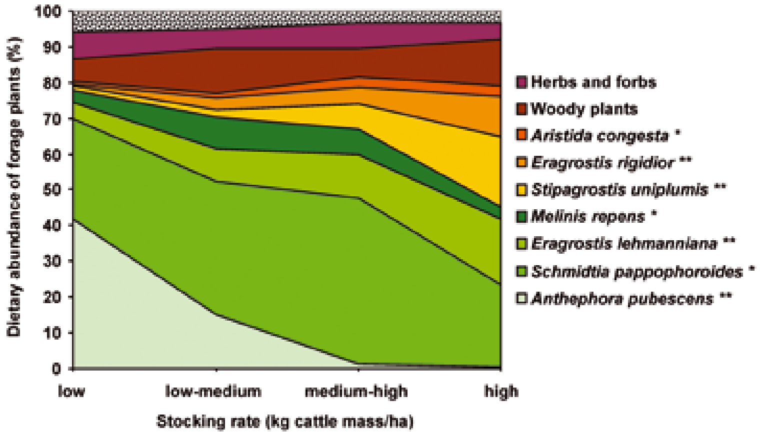

Figure 1. The composition of the diet of free-ranging cattle kept at various stocking rates in Namibia (*: $P < 0,05$; **: $P < 0,01$).

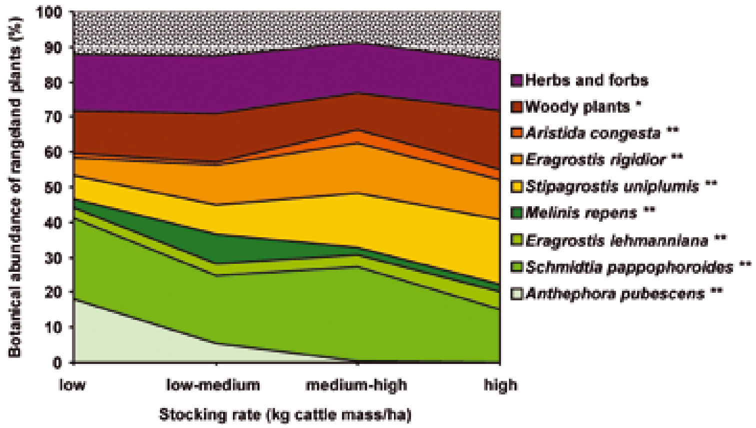

Figure 2. The botanical composition of the rangeland stocked by cattle at various stocking rates in Namibia (*: $P < 0,05$; **: $P < 0,01$).

cattle, even of indigenous breeds such as the Sanga, are overly reliant on just a small number of favourite forage plants for their diet. The same is true of various breeds of Namibian mutton and pelt sheep, which prefer *Schmidtia pappophoroides* grass above all others (Kamupingene *et al.*, 2005). These preferred grasses are very abundant in a savanna rangeland in good condition (Rothauge, 2005; 2006) and can indicate to the rancher whether or not the savanna can withstand the applied grazing pressure (Rothauge, 2006).

When the number of grazing livestock on the rangeland is increased, several things happen simultaneously:

- The livestock is forced to utilise other, less-preferred forage grasses to an increasing extent (Figure 1) because of the increased competition among foraging animals (Rothauge, 2006).
- The preferred grasses become over-utilised, weaker and eventually less abundant in the rangeland (Figure 2), thus forcing animals to utilise the less-preferred grasses even more (Rothauge, 2006).
- The nutritive value of the animals' diet decreases, as the less-preferred grasses contain fewer nutrients and are less digestible (Figure 3) (Rothauge, 2006). A degraded grass sward cannot meet the animal's maintenance requirement of nutrients, whereas a pristine grass sward offers enough nutrients for animal production at a medium to high level.
- The productivity of individual animals, as measured by their body mass, body condition and fertility, decreases (Figure 4) because the increased stocking rate is forcing them to consume proportionally more of the less-preferred grasses, which are less nutritious (Rothauge, 2006). This outcome is predicted by the Jones and Sandland (1974) model (Figure 5).
- The Jones and Sandland (1974) model (Figure 5) also predicts that the response curve of whole-system productivity to increasing stocking rate is bell-shaped: increasing the stocking rate will initially increase the productivity of the whole animal production system, even beyond the stocking rate at which the productivity of individual animals starts declining. This favourable relationship does not last long, however, as at a certain high stocking rate the decline in individual productivity exceeds the increase in

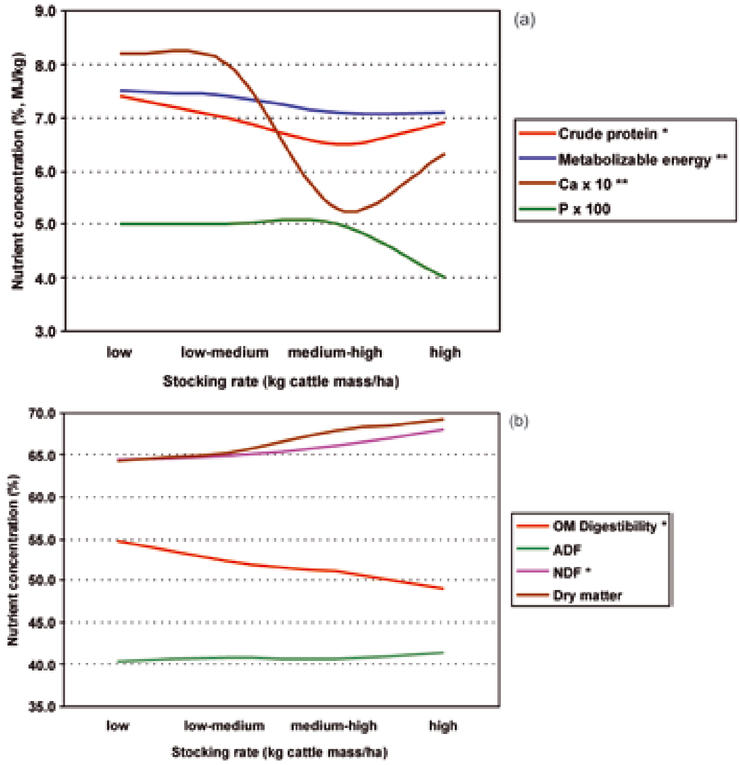

Figure 3. Changes in the nutritive value of the diet of free-ranging cattle in Namibia, due to increasing the stocking rate of the cattle.
(a) Crude protein, metabolisable energy, calcium and phosphorus.
(b) Digestibility of the organic matter, acid-detergent fibre, neutral-detergent fibre, dry matter content (*: $P < 0{,}05$; **: $P < 0{,}01$).

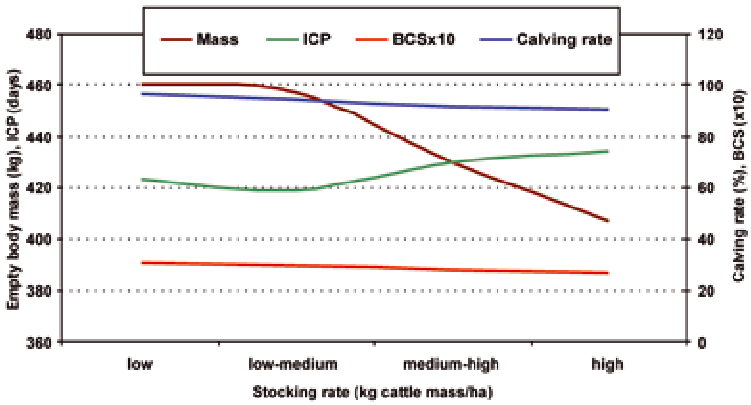

Figure 4. Changes in the productivity of individual cows, due to increasing the stocking rate of the cattle. Individual productivity is measured by body mass, body condition score (BCS), the calving rate and the inter-calving period (ICP) (all effects: $P < 0{,}01$).

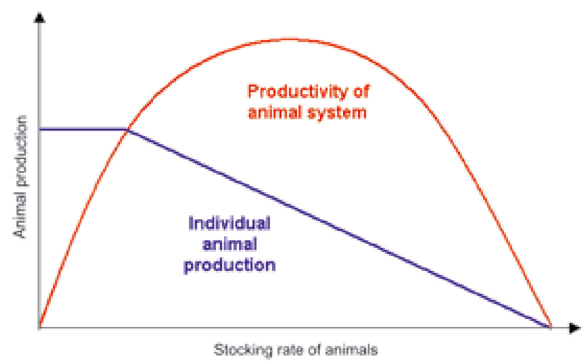

Figure 5. The Jones and Sandland (1974) model, explaining the relationship between animal productivity (individually and of the whole system) and the stocking rate of animals.

productivity, due to the addition of more animals to the system, and total system productivity starts declining. System productivity continues to decline until, eventually, at a very high stocking rate, animals die as fast as they are born and there is no nett production. The system is at the highest ecological stocking rate and on the point of collapse.

Under the conditions as examined by Rothauge (2006), the inflection point where system productivity increases less rapidly (i.e. a gradient change) was reached at a stocking rate of 45 kg cow mass/ha (Figure 6), even though the turning point of the system productivity curve was not witnessed as these high stocking rates were not applied. These experiments confirm that the Jones and Sandland (1974) model applies to livestock production systems in practice in Namibia.

- Before the system collapses, the rangeland undergoes major transformation, brought about by the increasing grazing pressure. Preferred forage grasses are steadily replaced by less-preferred and unpreferred forage grasses at stocking rates of up to 45 kg cow mass/ha (Figure 7). Once this particular stocking rate is exceeded, bush encroachment sets in and the previously perennial grass sward is replaced by an annual one (Figure 8). The degraded savanna has arrived at a new, lower level of productivity, as described earlier.

It is thus abundantly clear that if ranchers knew which grasses indicated whether or not the savanna is stressed by grazing pressure, they would be able to adjust that pressure in time to prevent serious and permanent damage to the savanna ecosystem.

SECOND PRINCIPLE: GRASSES NEED AN ADEQUATE RECOVERY PERIOD AFTER GRAZING

To retain the vigour of grasses that are eaten preferentially by grazing livestock and game animals, it is necessary for the rancher to heed the physiological status of the grass. Perennial grasses develop through several physiological phases during their annual growth cycle, intimately dependent on the climatic season (Wolfson and Tainton, 1999). Their response to defoliation by grazing animals depends on what stage of growth they are at and how much soil moisture, i.e. rainfall, is available (Wolfson, 1999).

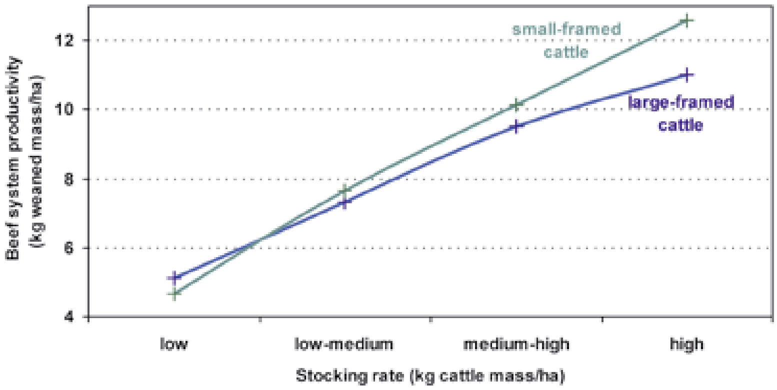

Figure 6. Changes in the productivity of a beef weaner production system in Namibia, due to increasing the stocking rate of the cattle. Two different breeds were used, a small-framed and a large-framed breed.

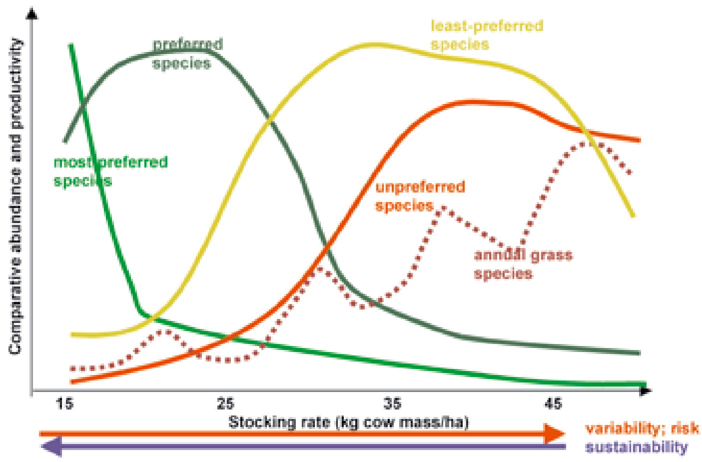

Figure 7. Transformation of the grass sward, due to increasing the stocking rate of grazing animals up to 45 kg animal mass per hectare, resulting in increased variability and risk, and decreased sustainability of the farming system. Examples of most preferred grass species are perennial *Anthephora* spp., *Brachiaria* spp., *Digitaria* spp. and *Panicum* spp., whereas *Schmidtia* pappophoroides, *Eragrostis lehmanniana* and *Melinis repens repens* are preferred species. Least-preferred species are e.g. *Stiapgrostis uniplumis* and *Eragrostis rigidior*, while most *Aristida* spp. belong in the unpreferred group.

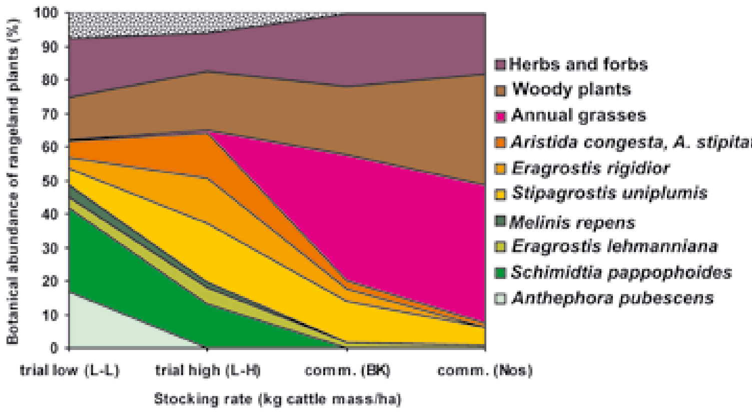

Figure 8. The botanical composition of the rangeland stocked by cattle at various stocking rates in Namibia. Stocking rates indicated by trial vary from 15 kg to 45 kg cow mass per hectare, while those indicated by 'comm.' vary from approximately 60 (BK) kg to 80 (Nos) kg cow mass/ha.

During Namibia's winter, which is cold and dry, perennial grasses are in a state of dormancy in which metabolic activity drops to zero. Defoliation of perennial grasses during their dormant period does not damage them unless defoliation is so close to the ground that the immature growing points (buds) at the base of the grass are removed.

Once the weather becomes warmer, the increasing daylight length and night temperatures stimulate perennial grasses to break dormancy; they start to grow and turn green. This initial 'green flush' is unsustainable, however, because it has not yet started to rain and growth activity is completely reserve-driven. Repeated defoliation during its initial growth stage damages the grass severely by stimulating it to re-grow, using its reserves. These reserves become depleted very quickly, and the depletion kills the perennial grass before the onset of the rainy season.

Once the rainy season starts, the growth of the grass is no longer reserve-driven, but supported by the availability of soil moisture. The green parts of the grass photosynthesise the carbohydrates needed to fuel its vegetative growth. Defoliation at this stage is not damaging, provided that the grass is left with enough green material: enough of its photosynthetic factory to operate and recover. Defoliation during the active or vegetative growth phase stimulates the grass to re-grow and tiller more, i.e. production is accelerated if grazing is not too close.

Later during the growing season, when the vegetative growth of the perennial grass has enabled it to amass a large surplus of carbohydrates, further vegetative growth stops and the grass starts producing seeds. Defoliation at this stage does little damage to the grass other than reducing the number of seeds and taking it back to vegetative growth. Since perennial grasses are persistent, they easily survive the occasional drop in seed production.

When daylight length decreases, the perennial grass translocates the accumulated carbohydrate reserves left after seeding, from the leaves, where they were formed by photosynthesis, to the basal parts of the stems and the roots, which serve as storage organs. Translocation prepares the grass for the coming of dormancy. The amount of carbohydrates stored in the roots determines the extent of initial growth early in the next growing season, so that repeated defoliation at this stage has severe consequences for the next season's early growth. After translocation and when the cold dry season sets in again, the grass becomes dormant – a strategy that enables it to survive for an indefinite number of years.

Annual grasses grow anew from seed each season. Their germination being triggered by rainfall events, their subsequent vegetative growth and seeding depends on follow-up rainfall events. If the follow-up rains are poor, the growth and development of annual grasses is equally poor. If they do manage to produce seed, they put all their carbohydrate reserves into it and have nothing left, so they die at the onset of the cold dry season. Their seeds persist for a number of years, waiting for favourable moisture conditions when they can grow and develop, and so maintain the species' presence.

From this physiological perspective, it is clear that both perennial and annual grasses should be allowed to go to seed before they are grazed. After a grazing event, they should be allowed to produce seed again before being re-grazed (Figure 9a). The better the rainy season, the faster the re-growth to seed and the more often the grasses can be grazed. If the rainy season is a poor one, re-growth will take a long time, due to the scarcity of soil moisture, so grazing should be delayed until the grasses eventually set seed.

The grasses of a savanna will not all go to seed at the same time. Soil fertility differs among patches, rainfall distribution is also patchy and the history of previous grazing differs among patches, so the grass sward will be a mosaic of different growth stages. Sub-dividing the rangeland by fencing it into camps of smaller area enables the farmer to graze one area at a time, leaving the grasses in the ungrazed camps to continue their physiological development. If the farmer is forced to re-graze a camp before its grasses have been able to go to seed, he has too many animals. This becomes particularly relevant during a drought, i.e. an unproductive rainy season when the soil moisture is so little that it takes perennial grasses a very long time to accumulate enough carbohydrates to go to seed, and annual grasses either do not germinate or they wither soon after germination.

If grasses that have already been grazed during the current season are re-grazed again before seed-set, their reserve status is lowered, and if this is repeated a couple of times, the grass will die (Figure 9b). Obviously,

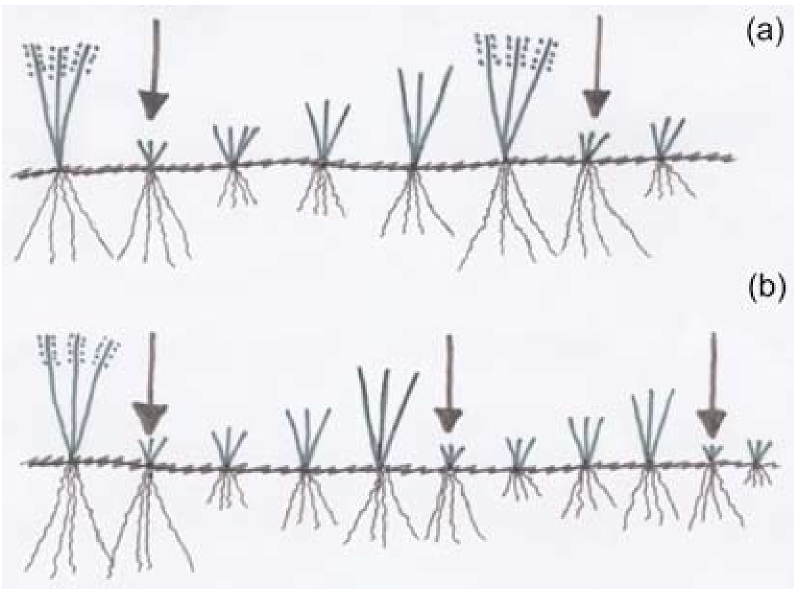

Figure 9. Schematic presentation of the effect of defoliation by grazing (indicated by arrows) on the vigour of a grass tuft:
(a, top) if grass tuft is allowed sufficient time to recover from previous defoliation and
(b, bottom) if grass tuft is not allowed sufficient time to recover from previous defoliation.

the most-preferred grass species, such as *Anthephora pubescens* and *Schmidtia pappophoroides*, will be re-grazed first, returning them to their initial, reserve-driven growth phase, whereas less-preferred grass species will not be defoliated and will go to seed.

The danger for a rancher who does not know the difference is that he will see grasses going to seed and think they are ready for re-grazing, when in reality the preferred species are still in the initial, vulnerable growth stage while only the less-preferred grasses are seeding. Re-grazing now will soon kill the preferred grasses, whose place in the grass sward will be taken by the less-preferred grasses. Transformation of the grass sward (Figure 7) is triggered in this manner; it will eventually lead to annuals replacing the perennial grasses and bush encroaching on the empty patches left by the dying grasses (Figure 8). Sustainable rangeland management thus requires the rancher to be able to distinguish between grass species preferred by his livestock or wild animals and those that are not preferred (Principle 1), and then to allow re-grazing only when the preferred grasses have gone to seed (Principle 2). He will have to rapidly adjust the number of his animals to the growth stage of the preferred grasses, which depends on the amount of rainfall received and boils down to 'the animal numbers tracking the rainfall' (Behnke and Scoones, 1992).

It is probably unnecessary to have a specific camping system that most facilitates sustainable utilisation of grasses, although little research into this particular topic has been done of late (e.g. O'Connor, 1985). In principle, the more camps there are at the disposal of a rancher, the easier it should be to give each camp an effective rest period between periods of occupation (Hoffman, 1997). This does not require a specific camping system, but instead a larger number of camps per herd of animals, since the emphasis is not on the grazing but on the resting of camps. The same effect can probably be obtained by reducing the number of herds on the farm (e.g. by combining some herds) and by an effective herding system in the absence of camps (e.g. in open access communal systems), but this would require further research.

THIRD PRINCIPLE: CREATE DROUGHT RESERVES

Droughts are a recurring feature of the Namibian climate. It has been estimated that six out of ten years are drier than average, two wetter than average and two about average (Du Pisani, 2003). A rancher who is prepared for drought conditions has a better chance of surviving the drought and resuming production afterwards than has a rancher who is blissfully unaware that the next drought is just around the corner (Rothauge, 2001). Two major grazing strategies are used by pre-emptive Namibian ranchers to cope with droughts.

The first strategy, which is the less risky of the two, makes use of deferred grazing. It originated at a time when ranches were still very large and most ranchers owned multiple ranches. Only two-thirds to three-quarters of every ranch would be utilised during the rainy season, allowing the remaining one-third or one-quarter of the ranch to rest for a complete growing season (Walter and Volk, 1954). The rested area had the chance to recover from previous grazing and to accumulate a lot of herbaceous matter for utilisation during the dormant season.

If the system of resting areas during the growing season is rotated around the whole ranch in a cycle of three to four years, every section has the chance to recover and so rangeland condition on the ranch improves. The size of the area on which grazing should be deferred during the growing season depends on the aridity of the area: the more arid, the larger the proportion of the ranch on which grazing should be deferred. In today's time of shrinking farm size, this strategy might no longer be viable.

The second strategy, making use of opportunistic management, is riskier but more suitable for smaller ranches. The core or nucleus herd of animals that the rancher wants to retain at any cost amounts to only about 60 % of the average carrying capacity of the ranch. The remaining carrying capacity is taken up by so-called 'filler' animals, i.e. animals that the rancher is prepared to part with in a hurry in the event of unfavourable rainfall (Behnke and Abel, 1996a; b; c). Herd composition is thus more flexible and, if a drought is about to strike, the rancher quickly disposes of the filler animals while their condition is still good, fetching favourable prices for these animals and saving his shrinking grazing for his nucleus herd. After the drought, the rancher quickly re-stocks with bought-in young animals to utilise the favourable grazing conditions. Thus, due to his opportunistic and anticipatory management, his herd size tracks the rainfall and he is able to maintain his core animals even in the event of a serious drought. This strategy requires well-developed marketing and transport systems, as there are in Namibia.

Both of these grazing strategies require that the rancher regularly determines herbaceous yield on his ranch. Various methods are available for this purpose, ranging from labour-intensive clipping of samples (Bester, 1988) to high-tech satellite imagery (Ganzin *et al*., 2005).

In addition to these two grazing strategies, ranchers can prepare themselves to survive a drought in various other ways. They should establish dryland cultivated pastures of indigenous perennial grasses on at least 5 % of their ranch, or on a bigger area if they live in more arid areas. The most fertile pieces of land, e.g. on river banks, should be used for this purpose. Such pastures should preferably not be grazed but instead used for harvesting hay. The hay can be stored and fed to animals during droughts (Rothauge, 2001). If enough hay is harvested, it can also be utilised opportunistically to enhance the condition of animals that are close to marketing. The most commonly used grasses for this purpose are *Cenchrus ciliaris*, which has a high yield but is not very palatable and requires phosphorus fertilisation, and *Anthephora pubescens*, which has a lower yield but is highly palatable, drought-tolerant and does not require any fertilisation. In the meantime, promising palatable grass species such as *Schmidtia pappophoroides* are currently under investigation.

In addition, ranchers should plant drought-resistant fodder crops on another 5 % or more of their ranch, preferably on poor soils and where erosion occurs, as these plantations will stop erosion. Exotic fodder crops such as *Atriplex* spp. (salt bushes), *Aloe* spp. (Mexican aloe) and *Opuntia* spp. (spineless prickly pear) are ideal for this purpose. These crops would not be harvested during good seasons but allowed to accumulate copious herbaceous matter, which would then be either grazed directly by animals or harvested, processed and fed out to animals during a drought (Rothauge, 2001). Most of these plants are not very palatable and need processing before feed-out, to limit digestive problems (e.g. laxative action, high salt intake, etc.).

Many old Namibian ranchers have their own, specially adapted drought-coping mechanisms brought about by long years of experience and it would be well worthwhile making a study of these.

FOURTH PRINCIPLE: RANGELAND IMPROVEMENT THROUGH BUSH CONTROL

It appears that gradual bush encroachment is an inevitable, albeit episodic event in savanna areas in which fire is excluded in order to safeguard grazing for domestic livestock (Rothauge and Joubert, 2002), i.e. most of Namibia's commercial ranching areas. Dense stands of mature bush cannot be controlled by fire, due to a lack of herbaceous fuel under their canopies and the high heat resistance of the woody stems. However, immature bush, saplings and recruits are highly vulnerable to fire and can be killed by a hot fire towards the end of the cold dry season, when the bush breaks its dormancy because of increasing daylight length and temperature. A 'hot' fire is one that burns slowly against the wind and remains close to the ground, so raising the temperature of the soil and causing greater damage to new growth than a 'cold' fire, which burns with the wind, travels faster and has less time to raise the soil temperature. Control by fire should be attempted only after a very productive rainy season, when a lot of unused herbaceous matter has accumulated (Bond, 1997). This not only makes for the hot fire that kills bush effectively but also allows the rancher the luxury of sacrificing some of his grazing for controlled burning on a part of the ranch, as there is more grass than his animals can consume. Such fires imitate the natural rhythm of a savanna.

Mature stands of bush have to be controlled by mechanical, chemical or biological means (De Klerk, 2004), of which biological control through fungi of the *Phoma* type is least effective in Namibia's arid climate. Chemical control is easy, but expensive and controversial in a country that prides itself on the production of 'organic' meat. A good deal of research has been done into chemical bush control, as it is a profitable undertaking for chemical companies that produce arboricides, and there are many different arboricides available for different situations. Also, some bush species, e.g. *Dichrostachys cineria*, are best controlled by chemical means only, as their suckering lateral root system allows bushes that have been chopped or burnt off to re-sprout so vigorously that they greatly exceed the original infestation.

Mechanical bush control is relatively cheap but tedious and slow. It is also highly selective and can be combined strategically with 'work-for-food' programmes to support the poorest of the poor. Having thinned encroached areas, aftercare by fire or heavy browsing should be applied, to prevent rapid re-colonisation by bush seedlings freed from the competition of larger bushes. Bush control should be spread around the ranch by systematically treating progressively larger areas of the ranch year after year. Ideally, this control should be combined with restorative measures aimed at rehabilitating the weakened grass sward that originally allowed the bush to encroach. An effective method is to chop off bushes, treat the stumps to prevent coppicing, turn the bush on its head over the stump and sow seeds of palatable perennial grasses under the canopy, where they enjoy protection from selectively-feeding herbivores for a number of years.

Since most encroaching bush species are also legumes, they create islands of fertility under their canopies where grasses grow preferentially (Rothauge *et al*., 2003). Chopped bushes can also be used to control erosion by brush packing along a contour or in an erosion gully. Of course, if the original cause of bush encroachment is not addressed, all these control measures will buy time only until the next cycle of encroachment occurs as a consequence of the symptoms but not the root cause having been treated (Rothauge and Joubert, 2002).

Where bush is controlled, the grass sward recovers quickly and grass production multiplies manifold; an effect that lasts several years before it tails off and stabilises at a considerably higher level of production than when the range was bush-encroached (Smit *et al*., 1999). Bushes are C3-plants that use water much less efficiently than indigenous grasses, which are C4-plants. However, bushes can extract water more efficiently from dry soil than grasses can, thus dessicating the soil and causing local aridification, to the detriment of herbaceous production (Stock *et al*., 1997; De Klerk, 2004).

Bush encroachment creates opportunities for secondary industries to benefit from bush control. Thick stems make good firewood and can be partially burned to produce charcoal, Namibia's latest export speciality. Smaller stems are chipped and compressed into briquettes, which are also exported. The newest development is to utilise whole bushes for the creation of electricity (Von Oertzen, 2007) through the process of pyrolysis (Honsbein, 2007), raising the prospect of harvesting bush sustainably in place of simply controlling it purely for improved rangeland productivity.

SUMMARY

Rangeland degradation and bush encroachment are problems at a landscape level that cost Namibian ranchers dearly and endanger the country's vast, extensive animal production industry, as well as the livelihood of the majority of the rural population. Most of the degradation is brought about by inappropriate rangeland management. By adhering to a few basic principles, adjusted and fine-tuned to every rancher's own unique situation, degradation can be prevented entirely or, at the very least, its impact can be reduced. It is of primary importance to know precisely which plants are eaten preferentially by the ranched animals, and to treat these plants in such a manner that their vigour is retained and their abundance in the rangeland increased. For perennial grasses, this requires safeguarding their recovery to seed formation after every grazing event. Droughts are inevitable in Namibia, but their impact can be lessened if precautions are taken in time.

Finally, rangeland should be rehabilitated through a combination of techniques of which bush control is the most important element. These actions should be taken together, as only a combined effort to improve rangeland management will improve the ranchers' prospects of remaining on their ranch.

REFERENCES

ADAMS, F. & WERNER, W., 1990. *The Land Issue in Namibia: An Enquiry*. Namibia Institute for Social and Economic Research, University of Namibia, Windhoek, Namibia.

BEHNKE, R.H. & ABEL, N.,1996a. Revisited: The Overstocking Controversy in Semi-Arid Africa. 1. Intensification or Over-stocking: When Are There Too Many Animals? *World Animal Review* 87 (2): 4–9.

BEHNKE, R.H. & ABEL, N., 1996b. Revisited: The Overstocking Controversy in Semi-Arid Africa. 2. Stocking Rates for African Pastoral Systems. *World Animal Review* 87 (2): 9–17.

BEHNKE, R.H. & ABEL, N., 1996c. Revisited: The Overstocking Controversy in Semi-Arid Africa. 3. Sustainability and Stocking Rate on African Rangelands. *World Animal Review* 87 (2): 17–27.

BEHNKE, R.H. & SCOONES, I., 1992. Rethinking Range Ecology: Implications for Rangeland Management in Africa. *Int. Inst. Environ. Develop. Issues Paper* no. 33. Overseas Development Institute, London, United Kingdom.

BESTER, F.V., 1988. Die Bepaling van Grasproduksie van Natuurlike Veld [Determing the Grass Yield of Natural Veld]. *Agricola* 6: 26–30.

BESTER, F.V., 1998. Major Problem: Bush Species and Densities in Namibia. *Agricola* 6: 21–25.

BOND, W.J., 1997. Fire. In: COWLING, R.M., RICHARDSON, D.M & PIERCE, S.M. (editors). *Vegetation of Southern Africa*. ch 18. Cambridge University Press, Cambridge, United Kingdom.

DE KLERK, N., 2004. Bush Encroachment in Namibia. *Report on Phase 1 of the Bush Encroachment Research, Monitoring and Management Project*. Ministry of Environment and Tourism, Windhoek, Namibia.

DU PISANI, L., 2003. Drought Monitoring in Namibia. *Proceedings, 10th Congress of the Agricultural Scientific Society of Namibia (Agrisson)*, 6–7 August 2003. Geological Survey of Namibia, Windhoek, Namibia.

ESPACH, C., 2007. Determining Grazing Capacity with the Aid of Remote Sensing. *Proceedings, 12th Congress of the Agricultural Scientific Society of Namibia (Agrisson), 3–4 July 2007*. Neudamm Agricultural College, Namibia.

GANZIN, N., COETZEE, M., ROTHAUGE, A. & FOTSING, J.M., 2005. Rangeland Resources Assessment with Satellite Imagery: An Operational Tool for National Planning in Namibia. *Geocarta International 20* (3): 33–42.

HOFFMAN, M.T., 1997. Human Impacts on Vegetation. In: COWLING, R.M., RICHARDSON, D.M. & PIERCE, S.M. (editors). *Vegetation of Southern Africa*. ch 21. Cambridge University Press, Cambridge, United Kingdom.

HONSBEIN, D., 2007. Opportunities and Challenges for Second Generation Biofuels in Namibia. *Proceedings, 12th Congress of the Agricultural Scientific Society of Namibia (Agrisson), 3–4 July 2007*. Neudamm Agricultural College, Namibia.

JONES, R.J. & SANDLAND, R.L., 1974. The Relation Between Animal Gain and Stocking Rate. Derivation of the Relation from the Results of Grazing Trials. *J. Agric. Sci. (Cambridge)* 83: 335–342.

KAMUPINGENE, G.T., MUKUAHIMA, G., ROTHAUGE, A. & ABATE, A.L., 2005. Comparative diet selection of the Damara, Dorper and Karakul sheep breeds at Neudamm Farm. *Proc. 9th Nam. Rangeland Forum, 16–18 August 2005*. p L9. Sandveld Research Station, Gobabis district, Namibia.

MAWF, 2006. *Agricultural Statistics Bulletin* (1992–2004). Directorate of Planning, Ministry of Agriculture, Water and Forestry, Windhoek, Namibia.

MENDELSOHN, J., JARVIS, A., C. ROBERTS & ROBERTSON, T., 2002. *Atlas of Namibia: A Portrait of the Land and its People*. Ministry of Environment and Tourism, Windhoek, Namibia.

O'CONNOR, T.G., 1985. A Synthesis of Field Experiments Concerning the Grass Layer in the Savanna Regions of Southern Africa. *South African National Scientific Programmes Report no. 114*. October 1985. National Programme for Ecosystem Research, Pretoria, South Africa.

OWEN-SMITH, N. & DANCKWERTS, J.E., 1997. Herbivory. In: COWLING, R.M., RICHARDSON, D.M. & PIERCE, S.M. (editors). *Vegetation of Southern Africa*. ch 17. Cambridge University Press, Cambridge, United Kingdom.

PAGOT, J., 1992. *Animal Production in the Tropics and Sub-Tropics*. MacMillan, London, United Kingdom.

ROTHAUGE, A., 2000. New Ecological Perceptions of Arid Rangelands. *Agricola* 11: 49–56.

ROTHAUGE, A., 2001. Drought Management Strategies for Namibian Ranchers. *Agricola* 12: 99–105

ROTHAUGE, A., 2005. Long-term ecological monitoring of the central Highland savanna of Namibia. *Unpublished report*. Neudamm Agricultural College, Windhoek, Namibia.

ROTHAUGE, A., 2006. The Effect of Frame Size and Stocking Rate on Diet Selection of Cattle and Range Condition in the Camelthorn Savanna of East-Central Namibia. *Ph.D. thesis*. University of Namibia, Windhoek, Namibia.

ROTHAUGE, A. & JOUBERT, D.F., 2002. A model of vegetation dynamics of the Namibian Highland savanna. *Proc. 1st Joint GSSA/SASAS Congress, 13–17 May 2002*. p 76. Christiana, South Africa.

ROTHAUGE, A., SMIT, G.N. & ABATE, A.L., 2003. The Effect of the Sub-Habitat below Savanna Trees on Soil, Grass and its Utilization by Cattle. *Proc. VIIth Int. Rangeland Congress, 26 July–1 August 2003*. pp 106–109. Durban, South Africa.

SCHOLES, R.J., 1997. Savanna. In: COWLING, R.M, RICHARDSON, D.M. & PIERCE, S.M. (editors). *Vegetation of Southern Africa*. ch 11. Cambridge University Press, Cambridge, United Kingdom.

SKARPE, C., 1991. Impact of Grazing in Savanna Ecosystems. *Ambio* 20 (8): 351–356.

SMIT, G.N., RICHTER, C.G.F. & AUCAMP, A.J., 1999. Bush Encroachment: An Approach to Understanding and Managing the Problem. In: TAINTON, N.M. (editor). *Veld Management in South Africa.* ch 10. University of Natal Press, Pietermaritzburg, South Africa.

STOCK, W.D., ALLSOP, N., VAN DER HEYDEN, F. & WITKOWSKI, E.T.F., 1997. Plant Form and Function. In: COWLING, R.M., RICHARDSON, D.M. & PIERCE, S.M. (editors). *Vegetation of Southern Africa*. ch 16. Cambridge University Press, Cambridge, United Kingdom.

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

VON OERTZEN, D., 2007. Turning Namibian Invader Bush into Electricity: The CBEND Project. *Proceedings, 12th Congress of the Agricultural Scientific Society of Namibia (Agrisson), 3–4 July 2007*. Neudamm Agricultural College, Namibia.

WALTER, H. & VOLK, O.H., 1954. *Grundlagen der Weidewirtschaft in Südwestafrika [Basics of Rangeland Management in South West Africa]*. Eugen Ulmer Verlag, Stuttgart, Germany.

WESTOBY, M., WALKER, B. & NOY-MEIR, I., 1989. Opportunistic Management for Rangeland Not At Equilibrium. *J. Range. Manage*. 42: 266–274.

WOLFSON, M.M., 1999. The Response of Forage Plants to Defoliation: Grasses. In: TAINTON, N.M. (editor). *Veld Management in South Africa*. ch 4.1. University of Natal Press, Pietermaritzburg, South Africa.

WOLFSON, M.M. & TAINTON, N.M., 1999. The Morphology and Physiology of the Major Forage Plants: Grasses. In: TAINTON, N.M. (editor). *Veld Management in South Africa*. ch 3. University of Natal Press, Pietermaritzburg, South Africa.