MANAGEMENT INTERVENTIONS TO OVERCOME SEASONAL QUANTITY AND QUALITY DEFICITS OF NATURAL RANGELAND FORAGES

K.P. Kirkman[1] and P.C. de Faccio Carvalho[2]

[1]University of Natal, Private Bag X01, Scottsville, South Africa. E-mail: kirkmank@nu.ac.za
[2]Universidade Federal do Rio Grande do Sul, Postal 776, Porto Alegre, Brasil. E-mail: paulocfc@ufrgs.br

1. INTRODUCTION

Rangelands essentially comprise geographical regions dominated by grass with or without scattered woody plants. Rangelands are often considered to function primarily as feed for livestock. In this view, conservation and biodiversity issues are secondary. The alternate view involves recognising rangelands as a biome without a specific function, but where there is an implied responsibility for inventory, maintenance and conservation (Blench & Sommer 1999). Most of the world's rangelands support grazing or browsing animals in a variety of systems ranging from commercial livestock enterprises on privately owned or controlled land, through commercial enterprises on communally owned and controlled land to subsistence farming, either sedentary or nomadic. On many areas of rangeland on several continents livestock are kept for purposes other than just commercial gain, and objectives of livestock owners vary tremendously as a consequence. Large tracts of rangeland have been formally set aside for conservation purposes, and contain a variety of indigenous herbivores, which are managed largely for conservation purposes with maintenance of biodiversity often a primary objective. An increasing number of private landowners, particularly in Africa, are converting from commercial livestock farming to commercial game farming. While commercial game farming is often seen as a form of conservation, it may differ from classic conservation, as the focus tends to be on utilising game species that generate an income rather than conservation for the sake of conservation in an altruistic sense. Also, the focus tends to be on selected game species rather than the diverse array of fauna and flora present in what is often a highly manipulated system. Irrespective of the livestock production system, game production systems or conservation objectives, any herbivore system on rangeland is dependant on the forage produced by the rangeland.

The quality and quantity of rangeland forage production (both graze and browse) varies tremendously depending on climate and a range of other environmental factors. These factors also influence seasonal fluctuations in growth rates, dormancy periods and seasonal variations in quality. These inter- and intra-seasonal quality and quantity fluctuations result in nutrient deficits that severely limit livestock production potential, particularly where animal movement is restricted by artificial boundaries. While wild herbivores are probably better adapted than domestic livestock to survive these deficits, restriction of movement enhances the effect of the fluctuations and may consequently compromise condition, reproduction rates and survival rates of wild herbivores.

These limitations to livestock production should be seen in the context of increasing world population, urbanisation and rising incomes with consequent increasing demand for food, particularly protein. Urban populations tend to consume more animal products than rural populations and there is also a positive relation between level of income and consumption of animal protein (Steinfeld, de Haan & Blackburn 1997). Both the human population and the livestock sector in developing countries are growing at an unprecedented rate (Steinfeld *et al*. 1997). Current population growth estimates require a global increase in food supply of 2% (Nolan *et al*. 2000). Coupled to the increasing population and livestock sector is a decline in rangeland area as the demand for arable land increases. Degraded cropland is often allowed to fallow and converts to a poor form of pasture (Steinfeld *et al*. 1997). This, as well as the impact of grazing pressure, points to a perceived decline in condition of rangelands around the world with concomitant decline in production potential and quality.

Rangeland managers have a wide range of options available to overcome these deficits. These options include high input strategies such as ameliorating soil fertility (Tainton *et al*. 2000), modifying species composition by including more productive grasses or legumes (Tainton *et al*. 2000), establishing forage trees (agro forestry), incorporating crop residues where available, replacing rangeland with cultivated pastures or low input strategies such as burning humid grassland to improve quality (Barnes & Dempsey 1992, Zacharias 1994) or to stimulate unseasonal growth and thus improve quality (Trollope 1999). Management of animals on rangeland involves manipulating three variables, namely animal movement (within and between seasons), animal numbers (stocking rate) and animal type (ratios between types), as well as reproductive patterns, which influence seasonal forage demand.

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Resting portions of rangeland for winter use (Kirkman & Moore 1995) is a strategy that can ration the forage supply to improve the seasonal fluctuation. Supplementing protein, energy, minerals or a combination using a concentrated source may rectify specific quality deficits. Livestock production systems can be modified to adjust the seasonal forage demand in an attempt to match supply and demand. The modifications would normally involve adjustment of the calving or lambing season, the marketing age of the offspring and the proportion of breeding animals to the total number. Ratios of wild herbivores can be adjusted to ensure optimal utilisation of available grazing and browsing forage.

All of the above interventions have impacts on both the livestock production system as well as on the rangeland. Some of the interventions involve intensification, which can be defined as making an additional input to achieve additional output (Behnke & Abel 1996). Other interventions involve no intensification other than management inputs, but rather focus on the utilisation of rangeland to ensure a reasonable supply of quantity and quality feed throughout the year. The impact of any interventions on the rangeland would usually be in the form of changes in cover or species composition of the grass layer and changes in bush species composition or density of savannas. Any negative impact on the rangeland would usually be attributed to a loss of rangeland output due to removal of too much biomass by animals at the wrong time.

2. IMPACT OF GRAZING ON RANGELAND

The impact of livestock grazing on rangelands is somewhat difficult to define and quantify in general terms. Classical succession theory models predict responses to both under- and over-grazing (e.g. Hardy, Hurt & Bosch 1999). In recent years alternative paradigms have been promoted where climatic variation supposedly has a greater impact on rangeland vegetation than grazing animals, implying that plant-animal interactions are less important than plant-climate interactions, particularly in arid and semiarid rangelands (e.g. Behnke & Scoones 1993). Drought induced herbivore mortalities supposedly mitigate any negative effects of grazing and allow for recovery of the rangeland while herbivore numbers increase. In response Illius & O'Connor (1999) suggest that grazing impact on rangeland is related to the presence of key resource areas, which sustain herbivores during the dry season. They argue that rangeland is more heavily utilised during the wet season where herbivores are sustained by key resource areas than rangeland where there are no key resource areas utilised during the dry season. This implies that the impact of herbivores on vegetation is important even where intra- and inter-seasonal climatic fluctuations are significant. Given that pastures or any form of intervention that improves forage quantity or quality, particularly during the dry season, may be regarded as a key resource in terms of the above suggestions, it is relevant to examine the impact of both growing and dormant season grazing on rangeland.

2.1 Impact of grazing during the growing season on rangeland

Evaluation of grazing impact during the growing season in humid grasslands in South Africa has revealed that grazing animals can have a severe negative impact on both the vigour (short term) and proportional species composition (long term) of the grass layer (Kirkman 2002a, Kirkman 2002b, Peddie, Tainton & Hardy 1995, Zacharias 1994, Barnes & Dempsey 1992, O'Reagain & Turner 1992, Barnes 1989a, Barnes 1989b). In particular, Kirkman (1999) found that the vigour of preferred (palatable) grasses declined during the season following grazing, while vigour of unpreferred (unpalatable) grasses increased during the following season, probably due to reduced competition from the regularly defoliated preferred grasses (Figure 1) with livestock type having a significant impact on species response. O'Reagain & Turner (1992), in a review of grazing research in southern Africa, emphasise the strong evidence showing that sustained heavy stocking has a negative impact on vegetation, particularly its ability to recover after grazing. Regular resting of humid rangeland during the growing season has been shown to compensate for the detrimental effects of grazing on vigour and productivity (Kirkman 2002b, Kirkman 1999, Peddie *et al*. 1995). The direct impact of grazing on grasses in the arid and semiarid regions has not been investigated to the same extent. It is expected that grass growth in arid areas will be more dependant on episodic rainfall and growth periods will be interspersed with dormant periods. While it is expected that grazing during a growth phase in arid areas may have similar impacts to the more humid situation described above, grazing during a dormant period within the growing season will probably not impact the vigour of the grass to the same extent.

2.2 Impact of grazing during the dormant season on rangeland

Considerably less attention has been focussed on the direct impact of dormant season grazing on vigour of rangeland grasses. Most studies indicate a negligible effect (Rethman, Beukes & Malherbe 1971, du Toit & Ingpen 1970). These findings are consistent with common understanding of the response of grass plants to defoliation (Wolfson 2000) and are likely to be similar to the effects of defoliation on grasses experiencing temporal drought during a growing season.

3. MANAGEMENT INTERVENTIONS

3.1 Soil fertility

Application of commercial fertiliser (particularly nitrogen and phosphorus) to rangeland generally increases productivity, but is likely to be economically viable only where neither moisture nor the growth potential of the plants will limit growth responses of the plants (Edwards & Booysen 1972). However, work in humid South African rangelands has shown that after fertilisation, preferred grass species are replaced by unpreferred species, making rangeland fertilisation ecologically undesirable (Tainton *et al*. 2000). It is common practice for farmers who pen their cattle at night to collect the manure and apply it to fields, which may be used for forage production. The impact of this removal of nutrients on rangeland productivity has not been quantified.

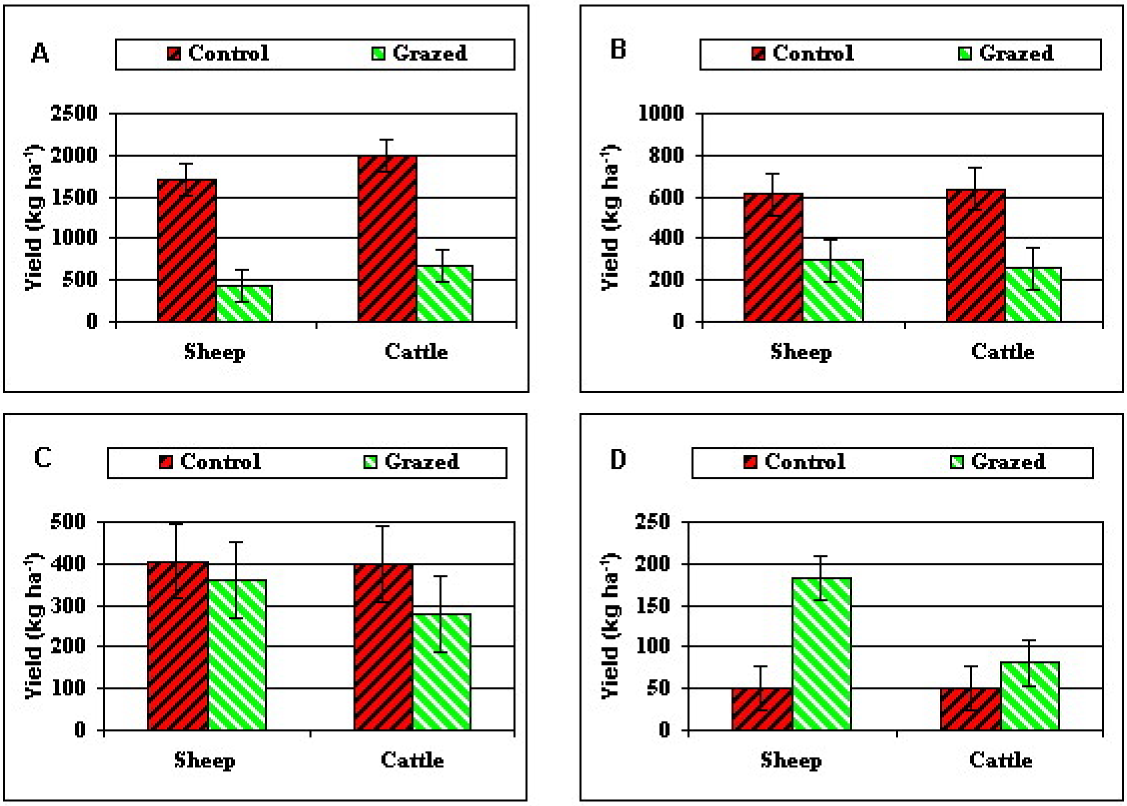

Figure 1. Effects of sheep and cattle grazing during the 1992/93 season on the yield of *Themeda triandra* (palatable) (A), *Heteropogon contortus* (intermediate) (B), *Eragrostis curvula* (intermediate) (C) and *Aristida recta* (unpalatable) (D) of the control and grazed plots measured during December 1993. The error bars represent the least significant differences ($P<0.05$).

3.2 Rangeland reinforcement

Where soil fertility and moisture permit, genetic limitations to rangeland production may be overcome by introducing seed of appropriate pasture grass or legume species (Tainton *et al*. 2000). Note that rangeland reinforcement should not be confused with establishment of cultivated pastures. Rangeland reinforcement is more of a low input attempt at changing rangeland species composition with the expectation of creating a sward with improved livestock production potential. As highly fertile soils and high rainfall do not usually occur together, this is likely to only be successful where soil fertility is ameliorated. This could then be considered a cultivated pasture.

3.3 Agro-forestry

Establishment of forage trees may provide significant amounts of additional forage, particularly for small farmers, with minimal disturbance of rangeland where trees are sited in relatively small, dense woodlots, along fence lines or around homesteads. Economic viability of agro-forestry systems is not easily quantified due the great variation under different circumstances.

3.4 Crop residues

Residues of summer grown crops form an extremely important part of many livestock production systems by providing winter feed that is high in protein or energy, depending on the crop. Crop residues are often costed into a livestock production system at a zero cost, as they are considered to be a by-product of a cropping system and may be wasted unless used by animals.

3.5 Cultivated pastures

Total replacement of rangeland with a cultivated pasture is probably the most intensive intervention for manipulating the seasonal quality and quantity of forage supply. It is also probably the most successful in terms of animal nutrition, but economic value may be tenuous (van Niekerk *et al*. 1987), depending on the economic value of the products in relation to the input costs. Pastures may be broadly classified as temperate or tropical (including subtropical), with both annual and perennial grasses and legumes falling into both categories. Generally, pastures matched to their environment have a similar growth pattern to the rangeland that has been replaced (e.g. tropical pastures grown in a tropical area). Productivity is usually greater than the original rangeland due to increased genetic potential and usually improved soil fertility. Irrigation may further increase productivity, reliability of production and may extend the growing season where temperatures are not limiting. Under favourable conditions, temperate pastures may be grown in tropical or sub-tropical conditions and may be productive during winter provided water is not limiting. Usually irrigation is required for temperate pastures under these conditions, although they may be adapted to higher altitude, cool aspects and wetter regimes in tropical or sub-tropical areas.

In many rangeland areas it has become common practice to utilise the rangeland as grazing during the summer growing season, and to conserve pasture growth for the winter dormant season. Ensiling the pasture, making hay or conserving the pasture in situ as foggage are common methods used for pasture conservation. The underlying logic appears to be that rangeland forage should be replaced with an improved quality alternative when there is a quantity or quality deficit.

The economic viability of including pastures in livestock production systems can be tenuous unless the value added to the marketable product is greater than the cost of the pasture. While this sounds simple, it is not always straightforward to determine the added product value attributable to including a pasture, and it is not always a simple matter to accurately cost the inputs made in pasture production. In situations where crop farming has become non-viable, usually due to unfavourable economics exacerbated by environmental limitations, landowners often to favour converting old croplands to pasture rather than allow secondary succession to proceed.

3.6 Burning

Humid rangelands are often burnt during the late dormant season or early growing season in an attempt to manipulate quality during the growing season. Indications are that grass quality of burnt veld is substantially greater than that of unburnt veld, with consequent improvements in animal performance in terms of gain per animal (Barnes & Dempsey 1992, Zacharias 1994). Humid rangelands are, in some areas, burnt during late summer to stimulate a green flush during autumn (Everson 2000). This practice is generally thought to be detrimental to rangeland condition, but under certain circumstances stability of the rangeland may be achieved without apparent degradation (Haschke & Kirkman 1994).

3.7 Resting for winter use

Where alternative sources of forage for the dormant season are not readily available, many livestock systems make spatial use of all available rangeland during the growing season, but are stocked at a rate that allows for carryover of enough residual forage at the end of the growing season to sustain livestock during the dormant season. This can be achieved by continuous or set stocking, or moving animals within the available rangeland using either a rigid or flexible rotation strategy. This approach generally allows for increased selective grazing during the growing season, with a theoretically large proportion of the more palatable tufts partially grazed during the growing season. The residual material available for dormant season use is likely to comprise relatively short, grazed or partially grazed, palatable tufts and longer, ungrazed, less palatable tufts. Quantity of forage available for dormant season use generally varies between seasons and is not easily quantifiable in such a system.

Other systems make use of certain areas of rangeland for wet season grazing and other areas for dry season grazing where certain areas are suited to dry season use and are thus allocated to the dry season. The wet season rangeland is grazed every wet season and the dry season rangeland grazed every dry season. Alternative approaches involve setting aside portions, on a rotational resting basis, of the total rangeland area available for use in winter as rangeland foggage (Kirkman & Moore 1995) where the season of use varies from year to year for a specific area. Both approaches of allocating set areas for dry season use allow for more formal feed budgeting on a spatial basis and should provide forage of a more uniform quality for winter use. Resting rangeland during the growing season should compensate to some degree for negative impacts of grazing on grass vigour as discussed above, at least in humid rangelands. Resting during the growing season allows preferred species to set and drop seed in contrast to non-rested conditions where mainly non-preferred species tend to seed prolifically.

This is probably more important in arid and semiarid regions where reproduction by seed is relatively more important than in humid regions. Any benefits of wet season resting would only be realised for the dry season rangeland where there is a specific wet and dry season area. Where rotational resting is applied, benefits could be realised over the whole area.

4. STOCKING RATE

The amount of forage produced from alternative sources for use during the dry season has a profound effect on the number of animals that can be carried on rangeland. During a defined growth season of eight months for example, the forage produced has to support animals for 12 months in the absence of any alternative sources of feed, or has to carry animals for a shorter period if there is a source of alternative feed. Consequently where alternative dry season feed is available, stocking rates on the rangelands tend to be heavier during the growing season. As an example, consider a beef production system where one animal consumes 10 kg of grass per day (3650 kg per year) and the rangeland produces 2000 kg ha^{-1} of grass available for grazing. In the absence of alternative feed sources for the dry season 1.8 ha of rangeland will be needed to sustain one animal for one year. Of the 2000 kg of available grass ha^{-1} produced during the 8-month growing season, 1333 kg (two thirds) will be removed during the growing season and 667 kg (one third) will be removed during the dormant season under ideal conditions. One third of the grass available for grazing will have been stored during the growing season for use in the dormant season, either spatially or by lenient defoliation. Where there is an alternative source of forage available to sustain animals for the four-month dormant season, then there is an opportunity to increase the number of animals and to manipulate the temporal defoliation pattern. Following the above example, the rangeland now only has to sustain the animals for eight months (240 days). One animal will thus require 2400 kg of grass from the rangeland during the eight-month grazing season, and 1250 kg of alternative forage. One animal will now require only 1.2 ha of rangeland to supply its forage requirements. An opportunity has been created to increase the stocking rate on the rangeland by 33%. On a more practical scale, 100 ha of rangeland could carry 83 cattle where there is a source of alternative forage for the dry season, or 55 cattle where the rangeland is the only source of forage for the full year. Few farmers or cattle owners would ignore such an opportunity to increase animal numbers. In addition, where the rangeland is only required to supply forage for eight months, the 2000 kg ha^{-1} of available grass is likely to be completely removed during the growing season with little or no carryover to the dormant season.

From the above example, providing sources of alternative forage for the dry season is likely to have a similar but probably greater effect on the rangeland than the key resource areas suggested by Illius & O'Connor (1999). This is in contrast to common perceptions that provision of alternative sources of forage, usually in the form of pastures, relieves pressure on the rangeland (e.g. Aucamp 2000). Reinforcing this concept on communal grazing areas, social forestry projects in India promoted stall-feeding with improved crossbred cows to relieve pressure on the rangeland, but no evidence emerged to show a reduction in grazing pressure. Similar projects promoting stratified production systems in North Africa and the Middle East also did not result in reduced grazing pressure (Steinfeld *et al*. 1997). It seems from these examples that intensification of production systems does not automatically reduce grazing pressure in communal grazing areas if the access to common grazing resources remains unchanged. From experience, most commercial livestock farmers tend to stock at a level matched to feed supply and demand on the rangeland. This is determined by a number of factors, including the sources of alternative feed and the periods during which alternative feed is available. When substantial amounts of alternative feed are available, the rangeland component of the annual feed supply tends to become the factor limiting animal production. It is not likely that any commercial farmer will then further constrain the limiting factor by decreasing stock levels on the rangeland merely because he has alternative sources of feed.

It follows then that incorporation of pastures or any of the other alternative sources of feed listed above will probably have an impact on the rangeland grazing dynamics, particularly the season and period of grazing, the seasonal distribution of grazing pressure as well as animal numbers in the system. Development of pastures and other alternative feed systems are generally considered in terms of the impact on animal production, and not in terms of the potential impact on the rangeland. This probably holds for commercial systems as well as communal and developing areas.

5. DEVELOPMENT OF RANGELAND LIVESTOCK SYSTEMS WITH AND WITHOUT ALTERNATIVE FEED SOURCES

The provision of some alternative source of feed usually involves some form of intensification and is likely, from the discussion above, to result in a greater impact on the rangeland while benefiting the livestock system. The impact of the alternative approach of using only rangeland for feed supply is likely to depend largely on stocking rate and season of use. The livestock system is likely to be influenced by the same factors.

5.1 Intensified systems

It is common practice for graziers who adopt some form of intensification, such as cultivated pastures, to utilise the rangeland during the growing season, and use the pasture (intensive feed source) during the dry season, usually in a conserved form. Following the argument above equating alternative dry season feed sources to the key resources defined by Illius & O'Connor (1999), this approach is likely to increase the grazing pressure on the rangeland. Generally, cultivated pastures will grow in the same season as the rangeland that it replaces, but should be more productive and of higher quality. Graziers do not use much of the improved quality during the wet season, when livestock generally have the greatest demand for quality feed (lactating females, young growing animals), but conserve it for dry season use. The process of conservation in any form always results in a loss of quality. Animals then utilise this conserved feed during the dry season. This is often a period when livestock have the lowest demand for feed quality (dry stock and pregnant females).

An alternative approach, which may be ecologically and economically advantageous, is to use the cultivated pasture during the growing season when productivity and quality are optimum and livestock demand for quality feed is at its highest, and to use rested rangeland during the dry season when quality demand is relatively low. This approach is logically sound from an ecological and economic point of view. Ecological advantages are outlined above. Economic advantages include the savings on not conserving pastures for winter use. Considering cash flow, any money spent on the pasture such as on fertiliser or machinery, is recovered relatively quickly, with a higher return due to livestock utilising the pasture when quality and quantity are maximum and when feed demand is greatest. If this pasture was conserved for dry season use, returns on money invested would take longer to materialise, and returns would be lower due to the loss of quality and quantity in the conservation process. Utilisation of rested rangeland during the dry season is based on using adapted livestock and timing the production system so that quality demand is at its lowest during the dry season.

5.2 Non-intensified systems

Provision of feed throughout the year from seasonal rangeland production remains challenging to commercial ranchers, communal livestock owners, nomadic herders and wildlife managers. In times before fences limited wildlife and livestock movement, animals probably moved, when necessary, to take advantage of rangeland spatial heterogeneity to ensure quantity and quality of feed throughout the year, although this spatial component of historical livestock and wildlife systems is probably not fully understood. Currently, livestock movement is generally limited on commercial ranches and many communal grazing areas. Many nomadic herders are also limited in their range of movement due to political boundaries and development, while wildlife movement and migration routes have largely been curtailed by agricultural and other developments. The consequent lack of rangeland spatial heterogeneity available to livestock implies that if a constant supply of quality feed is required from the rangeland from a homogeneous area, then some spatial heterogeneity has to be created to ensure constant feed supply. The alternative to utilising spatial heterogeneity for feed supply is that animals graze over the whole area available, but do not fully utilise the available forage during the growing season. The excess is then available for dry season use. In practice, most of the high quality forage will be utilised during the growing season, due to the animals' ability to select for quality, leaving an unknown quantity of lower quality forage for dry season use.

5.3 Creation of spatial heterogeneity for constant feed supply

Creating spatial heterogeneity for the supply of dry season feed involves resting portions of rangeland during the growing season for use in the dry season. The potential benefits of such resting strategies usually depend on the quality of this conserved forage during the following growing season. In humid rangelands (particularly in the southern African context), this conserved forage generally declines in quality during the dry season and is not acceptable to animals once new growth is available in the following growing season (such rangeland is referred to as "sourveld" in South Africa). In contrast, in semiarid and arid rangelands this conserved forage tends to maintain quality and is generally acceptable to animals during the following growing season (known as "sweetveld" in South Africa).

In sourveld areas it follows that any forage produced during a particular year should be consumed during that same year and any carryover will be wasted as forage, although it may be desirable for other reasons to have some carryover forage. With sourveld occurring in more humid climatic zones, rainfall and consequent forage production tends to be more consistent, with a lesser requirement for carryover forage from one year to the next. Several approaches to using spatially rested rangeland for consistent forage supply in sourveld have been discussed by Buntting & Zacharias (this conference) and Kirkman & Moore 1995). These approaches are largely based on concepts proposed by Venter & Drewes (1969) and centre around resting proportions ranging from 33% to 60% during the growing season for dry season use depending on conditions and requirements. It is important to note that the proposed large portions of rangeland rested during the growing season do not imply the need for a reduction in stocking rate. In practice, in systems where rangeland provides the forage supply throughout the year, resting provides spatial distribution of forage supply throughout the year instead of vertical distribution.

Forage requirements remain similar, and if productivity remains similar, the amount of forage removed by the animals remains constant per unit area, but differs spatially and temporally during the season. Indications are that resting may improve rangeland productivity and species composition for livestock production in sourveld areas (Kirkman 2002a, Kirkman2002b, Kirkman 1999, Barnes & Dempsey 1992, Barnes 1989a, Barnes 1989b) while the benefits to livestock production systems are discussed by Buntting & Zacharias (this conference). While quality of sourveld is often below the requirements for maintenance of livestock during winter, inclusion of supplements in the form of mineral and protein licks largely mitigates the quality deficits (Meissner 1999).

In sweetveld areas, carryover forage is generally accepted by animals during the following growing season and is thus able to play an important role in consistent forage supply in what is generally an inconsistent environment. With increasing aridity, rainfall tends to become more variable both within and between seasons. While in sourveld areas livestock managers can aim to have all or nearly all available forage removed by animals in any one season, in sweetveld areas one should make provision for erratic rainfall and have at least some carryover forage from one season to the next to ensure consistent forage supply. This implies a different approach to the management of sweetveld areas, with a requirement for resting greater proportions of rangeland during the growing season for use in the dry season and part of the following growing season.

One example (Kirkman 1997) of a practical approach to creating spatial heterogeneity in sweetveld for provision of winter-feed developed by a farmer (Harold Trollope on the farm "Brakvlei", Thabazimbi, South Africa) involves dividing the rangeland into three areas equal in grazing capacity. The year is divided into two seasons, namely a long season from 1 January to 31 July and a short season from 1 August to 31 December. The long season commences during the rainy season, thus allowing the first paddocks grazed an opportunity to re-grow and be utilised again towards the end of the season. Conversely in the short season growth only occurs at the end of the season after spring and early summer rains (Table 1). This sub-division ensures consistent supply of forage throughout the year in the area where it was developed.

Other advantages of this approach include:

- The three areas are systematically subjected to alternating seasons of utilisation.
- Utilisation is followed by a full twelve-month rest period.
- All livestock are confined to the third of the farm that is in use at the time. This is made possible because whenever a new third is made available for grazing after a rest, it has a standing crop of grass that has accumulated during the previous twelve months.
- Forage reserves in the form of rested rangeland provide a buffer against drought.

In practice this approach has resulted in greater grass productivity and lower bush density compared to adjoining properties. It must be emphasised that this approach will only be feasible where carry-over forage from one season to the next is readily acceptable to animals. This is usually the case in arid and semi-arid areas.

Table 1. The rotational grazing and resting programme for the system outlined above.

Year	Season	Area (equal grazing capacity)		
		A	B	C
1	Long	USE	Rest	Rest
	Short	Rest	USE	Rest
2	Long	Rest	Rest	USE
	Short	USE	Rest	Rest
3	Long	Rest	USE	Rest
	Short	Rest	Rest	USE
4	Long	USE	Rest	Rest
	Short	Rest	USE	Rest

This approach creates spatial heterogeneity (Table 1) in terms of vegetation structure (growth stage) that is used for ensuring consistent forage supply throughout the year.

5.4 Advantages of creating spatial heterogeneity

Apart from ensuring forage supply, such spatial heterogeneity is likely to benefit biodiversity, by creating diverse habitats ranging from short grazed rangeland to rangeland with more than a full seasons growth. In addition, this type of approach is likely to be the only means of applying intermittent fire as a management tool to semi-arid regions to counter bush thickening. In practice, fire has been used in the above system in an opportunistic manner after wet seasons, where adjoining properties did not have enough accumulated material to sustain fire.

This approach also allows the application of non-consistent management. As an example, from Table 1, area a would only be grazed in the long season every four years, alternating grazing in the short season with two complete 12 month rests covering different periods. This non-consistent management is likely to increase biodiversity, as opposed to consistent management that tends to favour a certain rangeland species composition.

6. DISCUSSION

The inter- and intra-seasonal quality and quantity deficits pose serious challenges for those wishing to feed livestock during the dry season each year, as well as during abnormally dry years. Most management interventions aimed at overcoming these deficits are developed by those interested in sustaining animals and not by those interested in conservation of rangelands. Consequently, many of the interventions mentioned above have or can have negative impacts on the rangeland. In particular, provision of alternative sources of feed usually only benefit the animals and not the vegetation. Future challenges involve developing livestock production systems that are more closely matched to the productivity of the resources available, with full understanding of the impacts of the spatial and temporal patterns of defoliation on the rangeland.

It is clear that there is an incontrovertible link between rangeland science (or rangeland ecology) dealing with management of natural vegetation in the presence of grazing or browsing animals and pasture science dealing with cultivated pastures as well as the sciences dealing with other sources of feed such as agro-forestry. A common thread is the impact of the animals on the vegetation and the impact of the vegetation management on the animals. A suitable term for this animal/vegetation dynamic may be production ecology.

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