Grazing Options for Arid Areas in South Africa

A RESOURCE FOR MULTIPLE USERS

PART II

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This report aims to investigate and review the grazing practices currently utilised in the Nama Karoo, as well as other grazing practices taking place in drylands around the world. The focus is to encourage sustainable, economically-viable livestock production in the Nama Karoo to benefit both local communities and the agricultural industry, as well as to support functioning ecosystems and the conservation of native biodiversity.

Contents

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1. General Introduction

Effective and sustainable grazing management in dryland habitats aims to retain or improve long-term veld functionality and the biomass of native, palatable forage resources, while capitalising on livestock productivity to ensure maximum economic profit and agricultural sustainability. In order for this to occur, a consistent forage supply should be maintained, while preventing overutilisation of vegetation (Todd et al. 2009). Importantly, it should be noted that rangelands are not homogenous and each farming context is different, thus it is difficult to provide specific grazing management recommendations for every scenario. Suitable grazing practices are likely to differ across farms, and will depend on each farm's focus, land-use and current environmental state.

This report should be considered a guideline focused on the Nama Karoo landscape, which promotes flexible, adaptive and measurable approaches to grazing management to ensure long-term agricultural productivity. We investigate a range of grazing options, but do not attempt to endorse any single grazing practice in particular. The intended audience includes anyone involved in the agricultural, environmental and conservation sectors in the Nama Karoo Biome, specifically farmers, municipal and government officials, conservation agencies and environmental consultants.

The Nama Karoo Context

The primary land-use in the Nama Karoo is extensive grazing of small stock, including sheep for wool and mutton and goats for mohair (Todd 2006). Cattle ranching in the north and east and game farming with indigenous antelope are also common (Mucina et al. 2006). Land ownership is mostly private or communal, and although ranches are fenced, they are typically quite large (4,000-15,000 ha). Due to the low productivity of the region and arid conditions, large areas are required to support livestock and wildlife (Mucina et al. 2006). Most livestock enclosures are supplied with watering points and are usually grazed on a rotational system with rest periods of several months to more than a year (Hoffman 1988). Threats to the Nama Karoo are described in detail in Part I (Best practice guidelines for sustainability and restoration in the Nama Karoo, South Africa) of this series of documents. For this document (Part II), it is important to consider that overgrazing, alien invasive species and the unsustainable abstraction of water have been noted among the most severe threats to biodiversity in the Nama Karoo (Todd et al. 2009). Included in this report is an additional focus on climate change, and the need to maintain a resilient agricultural industry and ecosystem in light of future climatic and environmental changes in dryland regions of southern Africa.

Two contrasting vegetation features dominate the Karoo landscape, namely herbaceous plants and woody Karoo shrubs (du Toit 2003). The growth cycles of these species differ, thus balancing forage ration through the year is challenging. Grasses are adapted to intensive, heavy grazing as they regrow rapidly from resting buds close to the soil surface, while shrubs take longer to recover as they will need to form new buds before they are able to regrow (Esler et al. 2006). Although forage quality of Karoo shrubs is typically high, the quantity available for herbivores varies seasonally and is largely influenced by rainfall (du Toit 2003). The Nama Karoo experiences unpredictable climatic events, including droughts and occasionally very wet years (Mucina et al. 2006).

2. Grazing Characteristics

The quantity and type of livestock and wild herbivores in a particular area, and the way in which they are managed are the most important factors affecting the ecological impact of a farming system.

Conceptually, every grazing management system in the Karoo has 6 important characteristics, which can be adjusted by the farmer (Esler et al. 2006). These characteristics will determine the number of animals that can be maintained sustainably, the economic cost of farm infrastructure and the long-term productivity and environmental impact of the farm given the specific environmental and climatic conditions (Esler et al. 2006).

2.1 Stocking Density

Stocking refers to the number of animals per unit area. This is considered the most vital factor for ensuring ecological sustainability in agricultural landscapes, because it is the pattern in space and time which controls the amount of vegetation biomass that is removed by livestock each year and therefore the impact the livestock will have on the vegetation each year (Todd et al. 2009). Animal production increases with stocking density until a peak/maximum production is reached, however, an increase in animals beyond this point will lead to a decrease in plant production, thus it is valuable to not allow stocking density to exceed that of the peak. Additionally, the health of vegetation declines when stocking density is too high, thus a compromise between these two considerations is essential for a productive, healthy and sustainable farming industry.

One of the golden rules is that, if the maximum animal productivity per hectare has been calculated, a decrease in this figure by between 10 and 15% per hectare, is usually appropriate for maintaining or improving the vegetation (Botha & Mellet 2002). High stocking rates are not sustainable in the long-term (Botha & Mellet 2002).

2.2 Grazing Period

This refers to the frequency and duration of occupation that animal stocks are retained within various camps on the farm, and refers to the pattern at which camps are alternatively grazed and rested. Effective grazing systems allow for greater livestock productivity, while ensuring that biodiversity is not negatively impacted. This and the stocking density control the degree of plant utilisation that occurs while the animals are in the camp.

2.3 Stocking Intensity (or Grazing Intensity)

Stocking Intensity combines both the animal concentration and the time period of grazing; it can be calculated by dividing the mean stocking density (e.g. animal units per hectare (AU/ha)) by the length of that period of grazing (e.g. AU/ha-day). This means that for a given stocking density, as the grazing period increases, the stocking density decreases (Scarnecchia 1985).

2.4 Rest period

The rest period is the duration of time a camp is left un-grazed to promote plant growth and reproduction. This usually depends on the grazing period, unless the camp is grazed multiple times during the year. Seasonal conditions and the rest period largely influence the extent of plant recovery. Finding the correct balance between veld utilisation and rest is one of the most important factors for successful veld management.

2.5 Herd composition

Different livestock species or breeds may differ in their preference for particular plant types or species, in their degree of selectivity (Brand 2000), or in their quantity or rate of consumption. Therefore, because different species and breeds of livestock utilise the landscape in different ways, the herd composition will largely affect the pattern and degree of utilisation of the landscape.

2.6 Camp size

This feature influences the range of stocking densities and grazing periods that are possible.

Stock density is the number of stock present on the land at any given time and is really an indicator of management technique. Stocking density (head/ha) refers to the number of stock per hectare on a grazing area or unit at any one time and is usually used to describe the number of stock per unit area in a high-density grazing situation.
The most important consequence of stocking density is that it affects the rate at which plant material is removed from the veld and consequently largely determines how long animals can stay in a camp.

Stocking rate is defined as the number of animals on a given area of land over a certain period of time. Stocking rate is usually calculated at the level of the entire farm and not at the level of the specific camp that is being grazed. Stocking rate is generally expressed as animal units per unit of land area. Carrying capacity is the stocking rate that is sustainable over time per unit of land area. It attempts to match the productive capacity of the land with the consumptive needs of the livestock. It is a year-long measure of how much livestock the land can support. So put in simple terms, stocking rate is just a measure of the land's carrying capacity. Stocking rates are regulated by the Conservation of Agricultural Resources Act of 1983 and may not be exceeded, unless exemption is obtained for a particular farming unit.

3. Principals of Best Practice

- Plants must be given the opportunity to grow, flower and disperse seed. This should occur during the growing season, at a time when herbivores are excluded from the camp. These periods need to be long enough to allow favourable and palatable species to grow, flower and set seed. Not all camps can be rested in the same season, therefore rest periods need to be alternated seasonally, but rest after rainfall or rest during the growing season is particularly favourable. Not all species reproduce in the same season, thus varying the seasons during which the veld rests accommodates recruitment of all species.
- Overstocking will more than likely lead to degradation over the long-term, thus the recommended stocking rate of the region should be considered.
- Stocking rate and the duration of the grazing and rest periods should be regulated by forage availability to allow sufficient recovery of the lost plant biomass. Additionally, rest periods are fundamentally important during wet years for sufficient veld regeneration.
- The aim of supplementary feeding is to prevent energy and mineral deficiencies in livestock. Additional feed provision in the form of bulk fodder (e.g. Lucerne) may cause livestock and game to have a detrimental impact on the veld, especially during drought conditions, because their condition is no longer related to veld quality and stocking density is kept "artificially" high.
- The selected grazing system should be flexible and adaptable in light of unpredictable climate conditions or other unexpected circumstances. A forage reserve should be maintained capable of supporting a breeding stock for a number of months.
- Farming practices developed in Grassland or Savannah biomes may rely on more consistent rainfall regimes compared to the drier, unpredictable conditions of the Nama Karoo, thus rest periods may need to be longer than recommended.
- In the Nama Karoo, predicting grazing capacities and stocking rates is difficult due to the erratic rainfall, sparse vegetation cover and large species diversity (du Toit 2001). A small stock unit (SSU), e.g. a sheep or goat, is roughly equivalent to 1/6th of a large stock unit in terms of its forage intake. A large stock unit is defined as the equivalent of one cattle with a body weight of 450 kg, gaining 500 g per day, with the energy requirement of ± 75 MJ ME / day (Herselman & Olivier 2009).

Regular and effective monitoring of key vegetation indicators allows ranchers to recognise detrimental veld conditions at their earliest stages, and adapt the key grazing characteristics (stocking density, rest period etc.) accordingly in order to prevent further damage. Key vegetation indicators can be selected based on their abundance and ranged in lifespans and palatability (Vorster 2017). In order to identify changes in the veld condition, baseline measurements should be recorded. Vegetation monitoring should be conducted across a range of sample plots, which together make up a representation of the farm. Vegetation monitoring should be repeated within the same sample plots at the same time of year each year (Vorster 2017). In the semi-arid Karoo, the most suitable time is at the end of the growing season (du Toit 2003).

4. Types of Grazing Systems

First and foremost, grazing systems are divided into two main categories: Continuous Grazing Systems and Rotational Grazing Systems. In both cases, the systems can be implemented either with or without camp fencing. Each grazing system will have positive and negative attributes which need to be considered under the specific context in which they will be utilised. No one grazing system is perfect, and can be endorsed as best practice. Additionally, it is only through long term monitoring of key indicators that one is able to effectively quantify the effect of a given grazing system. Too often, the comparison between a range of grazing practices is based on subjective opinions and circumstantial evidence. Among these, no grazing practice stands out as the most effective under all environmental and farming conditions. Additionally, the farm management activities, such as monitoring veld condition, repairing fences, and preventing, mitigating or rehabilitating land degradation, are often just as important, if not more important for sustainable farming, than the choice of grazing practice utilised.

4.1 Continuous Grazing

Only one feature is altered in this simple grazing system, namely the stocking rate. Livestock or wildlife have continuous, unrestricted access to one area of vegetation. At high stocking rates, veld condition will suffer, but at low stocking rates, economic return per unit area may be low. This grazing system is not common among private livestock farmers in the Karoo (Todd et al. 2009). However, continuous grazing is common on Karoo game farms, as game is not easily moved between camps (Esler et al. 2006), thus the utilisation of this approach is likely to increase with the increasing transition from livestock to wildlife-dominated land use. This approach is practiced on communal lands, where there are no camp fences and herding is no longer practiced (Salomon et al 2013). At low stocking rates, animals are highly selective, and will forage on the best quality graze material.

Continuous grazing	
Advantages	**Disadvantages**
Fencing costs reduced.	Overgrazing of palatable species is common.
Management level is low.	Palatable plants are not given the opportunity to grow, reseed and recover.

4.2 Rotational Grazing

Rotational grazing can be broadly defined as those systems where periods of defoliation (grazing) are alternated with periods of rest. There is a range of rotational grazing systems which differ in their methods and goals (Esler et al. 2006). Generally, rotational grazing can be divided into two main categories, those that make use of short grazing periods of less than one month; and those that utilise longer grazing periods (several months) (Todd et al. 2009). Rotational grazing is practiced on some communal lands, in the absence of fencing. In these cases herders move the livestock strategically to avoid overgrazing and herd competition at water points (Salomon et al 2013). Alternating between periods of grazing and rest will allow plants to recover, grow and reproduce, provided that rain falls during the rest period. Rest periods should be seasonally staggered to allow plants with differing growth cycles (e.g. grasses and shrubs) to complete their life cycles.

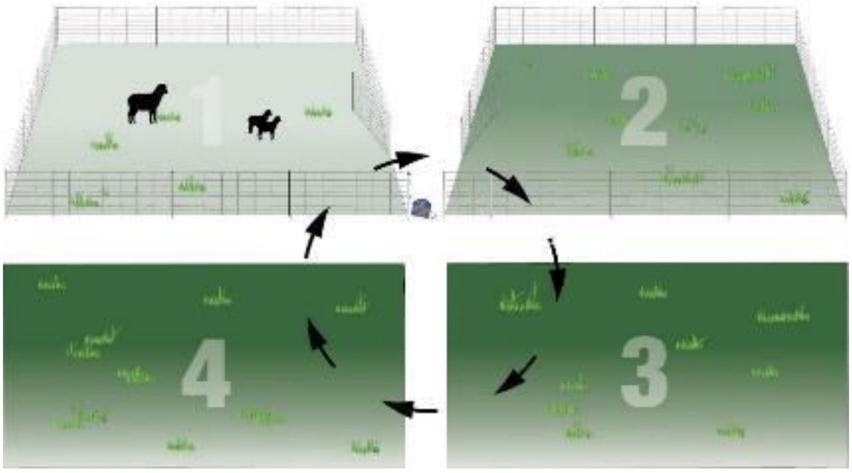


Figure 1. Schematic diagram showing the concept of rotational grazing, where camps/pastures experience alternating periods of rest and grazing.

4.2.1 Fewer Camps or Longer Grazing Periods

These grazing systems were designed by the Department of Agriculture at Grootfontein in the Eastern Cape, and generally require less infrastructure in the form of fencing and less demanding management. Grazing durations of 2-6 months occurring alternatively with long rest periods. Rotational Grazing systems have two to eight or more camps. Rest periods are generally staggered, so that each camp is grazed during a different season each year. The rest periods allow plants to recover, while the grazing periods (defoliation) promotes growth. Seasonal variation allows plants that are active only at certain times of the year some respite during alternate seasons. This is particularly important to promote the growth of both Karoo shrubs and grasses.

Fewer Camps or Longer Grazing Periods

Advantages	Disadvantages
Fencing costs reduced.	One school of thought is that the periods of occupation (2-5 months) are too long, thus leading to weakened plant health.
Management level is low.	Animal condition may decline toward the end of the longer grazing period due to fodder availability, which can affect conception rates and mass gain.
Longer rest period allows the recovery of both shrubs and grasses.	Limited flexibility, particularly where fewer camps are available, may not allow adequate response to the rainfall variability in semi-arid Ecosystems, which cause variability in forage production.

From a practical point of view, the grazing approach utilised by each farmer may differ somewhat from those options described above, as this list is not exhaustive, however, in most cases the practices utilised can fall generally into one of the options mentioned. System variations can be considered in light of current, local circumstances on each farm, or a combination of approaches can be utilised.

4.2.2 Multi-Camp Rotational Systems

a. Non-Selective Grazing (NSG)/Short Grazing Periods (less than a month)

John Acocks' research in the 1960's encouraged farmers to force their livestock to graze non-selectively, in order to allow more palatable species to out-compete and dominate less palatable species, and to reduce degradation in the Karoo (Hoffman & Cowling 2003). This system aimed to mimic the natural grazing patterns of large wild, migrating herbivores that would have occurred before land conversion of the colonial times (Hoffman & Cowling 2003). This pattern involves high intensity grazing for short time periods, usually, of less than two weeks, and if possible involves mixed herds of livestock. Livestock are enclosed in very small camps, which may be electrified. Following grazing, the camps are rested for at least one year. High animal densities reduce selective grazing, thus promotes the ingestion of unpalatable (but not poisonous) plant species and therefore preventing unpalatable species from having a competitive advantage (Hoffman & Cowling 2003). NSG, as designed by Acocks, is probably one of the least common grazing systems in the Karoo today.

Non-Selective Grazing

Advantages	Disadvantages
Maintains high stocking densities, which may compensate for any drop in livestock performance (income generation).	Requires a high level of management, labour and experience.
Long resting periods allow plant recovery, flowering and seeding.	Incorrect management may cause severe degradation, e.g. trampling unsuitable soil or trampling for too long can increase soil compaction, and decrease infiltration.
If soil is suitable high-intensity trampling can improve water infiltration.	Requires small camps, and extensive fencing (additional fencing costs can be expensive).
Trampling the rest of the plant serves as organic litter & protects soil from sun and erosion.	Crowded animals require protein supplements.
Pastures rest for longer to improve production.	Animal condition may be poor, and conception rates and mass gain is generally low.
Uniform urine and manure distribution (nitrogen fertilization).	

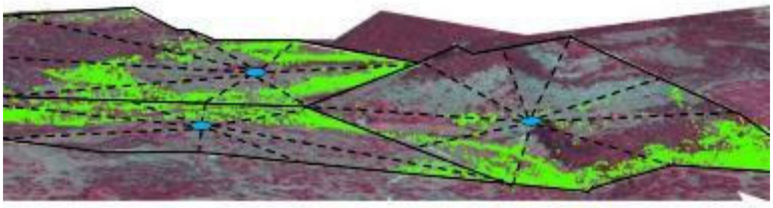
b. Holistic Resource Management (HRM)/Short Duration Grazing

Also termed: Holistic Planned Grazing (HPG), high density grazing, or Savory Grazing Method

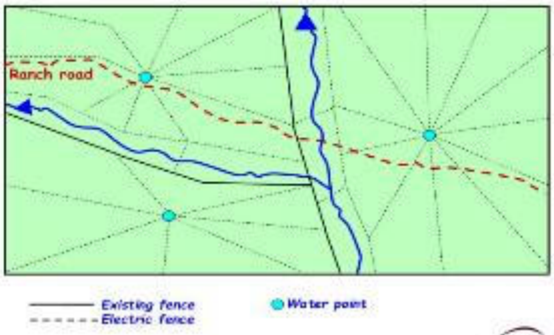
This system is an adaptively managed, time-controlled rotational grazing system similar to the Non-Selective Grazing system, as grazing durations are short (but for a different reason). It was developed in Zimbabwe in the 1970's by Alan Savory. Grazing palatable species often, may stimulate plant growth and promote an increase in production with large quantities of livestock. Disturbance by a large group of animals will break up soil crusts, and promote ecosystem services, such as decomposition, mineral cycling and plant growth. Short resting periods of about 2-3 months are usually exercised, which depend largely on the rainfall. The HRM system is commonly associated with the wagon-wheel camp layout, but this is not essential. The wagon-wheel layout has a central watering point with camps radiating outwards.

- The time duration that animals spend in a camp is based on the grazing plan, and the actual offtake of forage (usually 50 – 70%). Generally, this system utilises short grazing periods of one to seven days.
- The rest period is based on plant recovery biomass, which will depend largely on rainfall and season.
- Veld condition should be monitored every day to avoid degradation.

- Record keeping is encouraged and allows farmers to identify possible reasons for successes and failures.
- Veld condition and recovery is largely influenced by soil type, rainfall and vegetation type.



Teague et al. 2011; 2013



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Holistic Resource Management/Short Duration Grazing	
Advantages	**Disadvantages**
Maintains high stocking densities.	Requires intensive management.
Greater plant production has been documented in areas of high rainfall (Hawkins 2016).	Animal condition may be poor, and conception rates and mass gain is generally low (animals not given the opportunity to select preferred forage).
Integrates business management principles, such as goal setting, monitoring, adaptation and accounting, with ecological concepts.	Some studies suggest that if rainfall is <500mm/year, this system can have negative effects on plant production (kg/ha) (Hawkins 2016).
Uniform urine and manure distribution (nitrogen fertilization).	Karoo shrubs do not respond as rapidly as grasses (this system was designed for Grasslands).
Once livestock become accustomed to rotation they are easy to move and handle.	Requires small camps, and extensive fencing (additional fencing costs can be expensive).

c. Multi-paddock and Deferred Rotational Grazing

Also termed: The Group Camp Approach

In this system the farm is sectioned into a number of independently-functioning rotational landscape units, such as riverine, mountain or pediment units, which differ in productivity, plant composition and carrying capacity (Hoffman et al. 1999). This grazing practice was developed by Piet Roux for farms comprising a range of vegetation or landscape types. Each landscape unit is fenced and then sectioned into a set of camps, comprising of the same landscape or veld type (Teague et al. 2011, 2013). Sets of camps across landscape units are then grouped in management units to include camps with different purposes or those to be utilised during different seasons (Hoffman et al. 1999). A flock of animals are then assigned to one set of camps, and rotated through each camp, with varying resting and grazing periods (Esler et al. 2006). There are many variations to the group camp approach. The design of this grazing system is flexible, and can comprise a range of management techniques (such as intensive, non-selective grazing for short periods of time) (Hoffman et al. 1999). The grazing period of a set of camps should be rotated from one year to the next, because different vegetation types grow, flower and set seed at different times of the year, and all vegetation types will need a chance to recover (Hoffman et al. 1999). There might be as few as three or as many as 20 or 30 camp groups on any farm.

Example of a four camp grazing system (Saayman 2016):

	Dec/Jan/Feb	March/ Apr/May	Jun/Jul/Aug	Sep/Oct/Nov	Rest
Year 1	Camp A	Camp B	Camp C	Camp A	Camp D
Year 2	Camp B	Camp C	Camp D	Camp B	Camp A
Year 3	Camp C	Camp D	Camp A	Camp C	Camp B
Year 4	Camp D	Camp A	Camp B	Camp D	Camp C

In this case, only three groups are used annually, while the fourth group of camps is rested for a whole year and only used again for grazing in the third grazing season. In this way the group is rested for 18 months in total after which it gets intermittent rest for 6-9 months over a four year period. The 18-month rest period follows after the group has been used for grazing twice in the previous calendar year with only six months of rest between the grazing periods. This system can also be applied on farms with few camps, as a four camp system can followed on the same basis as a four-group camp system (Saayman 2016).

Advantages	Disadvantages
Simplified management, which is easily adaptable.	Where fencing by vegetation or landscape type is advocated, this may requires in some cases extensive fencing, which is very costly.
Different flocks can be rotated at different rates.	Where the system is strictly adhered to flexibility may be limited in the case of fluctuating environmental conditions on different parts of the farm.
Less maintenance and labour required.	Rainfall variability in semi-arid ecosystems causes variability in forage production, as such if carrying capacities are not adjusted, over-utilisation of veld may occur (pre-determined/fixed stocking rates often accompany this system).
Flocks graze the whole landscape and select a wider variety of plant species.	

d. Herding as a rotational grazing approach

In some cases social, economic or cultural barriers preclude the option of fencing rangeland. In order to avoid the financial cost of fencing, and the time and labour it takes to erect and manoeuvre camp fences, herding can also be used as a means of manipulating grazing patterns of livestock. This method allows for flexibility of livestock movement, but requires intensive labour to prevent severe degradation. The use of fenced grazing camps on commons is challenged by some authors. The approach of herding to achieve rotational grazing as an alternative to fencing is promoted, and various potential benefits such as improving rural livelihoods, reviving customary practice, reducing stock theft, reducing predation and improving biodiversity management are explored (Salomon et al 2013).

Advantages	Disadvantages
No additional fencing costs.	Requires high intensity labour with good agroecological and livestock knowledge.
Flexibility of livestock movement in response to environmental conditions and forage availability.	Animal condition may be poor, and conception rates and mass gain is generally low unless the system is carefully implemented.
Simplified, and adaptable management.	Requires cooperation of communities or villages over large areas, which can be very challenging.

4.3 Practices to avoid

- Overstocking, especially in areas sensitive to soil erosion, such as along riverbanks, on slopes, or in areas where interspace grazing can occur (de Beer 2016).
- Continuous grazing if medium or high stock densities are required.
- Repeated grazing within a single growing season or annually in the same season (i.e. resting season should vary each year).
- Use of unsuitable livestock breeds and extra-limital/exotic game breeds.

Overgrazing occurs more easily on veld in a poor condition compared to that in a good condition because there are fewer palatable plants and each plant is therefore more heavily browsed. Overgrazing and environmental degradation is possible regardless of the type of livestock or game present in a rangeland.

4.4 Farm Infrastructure

- Livestock should have access to clean, fresh water, and regular assessment should be made of the quality and quantity of water supply, playing specific attention to feedlot stock, and lactating females.
- Water supply infrastructure should be inspected regularly and well-maintained to conserve water and prevent overuse or wastage.
- Positioning rotational grazing camps around a central water point which may serve a number of grazing camps ensures that land degradation associated with water points is limited to one central region.
- Heavy grazing pressure and trampling around water points, leading to vegetation and soil degradation, is well documented in southern Africa (Andrew 1988). In arid rangelands, the effects of livestock on vegetation are exacerbated by slow vegetation recovery in limited rainfall

areas (Ross 1995; Farmer 2010), thus water points should be positioned away from sensitive areas, such as escarpments, riparian areas, wetlands, special indigenous plant communities, breeding sites of native wildlife, and archaeological or historic sites.

- Similarly, roads should avoid these sensitive areas.
- Roads should be adequately drained to prevent large scale runoff and erosion, additionally they should cross waterways at right angles to divert runoff, thereby preventing erosion along tracks.
- Fencing, although expensive, is a valuable means of protecting livestock and game from predators, disease transmission and theft.

In the game farming industry, fences of 1.8 m are recommended for most antelope, although a fence of 2.4m is needed to contain Kudu. For larger, more dangerous game, such as buffalo, specific fencing regulations may apply, as such provincial conservation authorities must be consulted for specifications.

5. Livestock Differences

The diet of different herbivores grazing in a particular area varies depending on physiological requirements and limitations, behavioural preferences, anatomy, and body size (Botha et al. 2001). Accordingly, the stocking density and grazing capacity will differ across stock types (Botha et al. 2001).

Afrino Sheep

As small-stock species utilise different components of the veld, it is believed that by combining different small-stock breeds, it might be possible to apply a heavier stocking rate, without vegetation deterioration. A study on the diet selection of different small-stock breeds, including Afrino, Dorper and Merino sheep and Angora goats was conducted in the arid Karoo to investigate this theory (du Toit & Blom 1994). However, the study failed to confirm this hypothesis. There was too little (3-5%) difference between the selected diets of the various small-stock species during the growing season to validate the assumption that by combining small-stock species, one can increase the stocking rate (du Toit & Blom 1994).

Merino Sheep

Merino sheep contributed to the development of the Afrino and Dohne Merino breeds (Snyman 2014a). Merinos are by far the most abundant sheep breed in South Africa, at 11.25 million, they make up more than 50% of the total number of sheep in the country (Snyman 2014a). The average body weight of Merino flock ewes at Grootfontein is 51 kg, while the average 12-month body weight of rams and ewes is 48.7 and 45.1 kg, respectively (Snyman 2014a).

Described in Farmers Weekly as an easy-care, dual purpose breed, the **Afrino sheep** is a locally developed composite dual purpose meat and white wool breed (Snyman 2014b). Although fleece quality will decline during drought conditions, it is reported that Afrino ewes will still produce a lamb as they proficiently convert forage to milk. Afrino hamels (wethers) do well on sour grassveld. In this case, hardiness is measured as the ability of an animal to survive, produce and reproduce under harsh environmental conditions, without supplementary feed (Herselman 1992). Average body weight of adult Carnarvon Afrino ewes was 65.9 kg (Snyman 2014b).

A study investigating dietary overlap of various stock types conducted in Mixed Karoo veld revealed that **Dorper sheep** and **Merino sheep** showed an average similarity in their diets (Botha et al. 2001). Both Merinos and Dorpers selected for the palatable Karoo bush during winter, and the unpalatable component during spring (Botha et al. 2001). At an age of 11-months the average body mass of Dorper rams and ewes is 80.0 kg and 65.2 kg, respectively. Merino sheep and **Boer goats** showed approximately 50% similarity in their diets (Botha et al. 2001). Mature boer goats weigh on average 80 kg, while, 100-day weaning buck and doe kids weigh 27 kg and 24 kg, respectively (Snyman 2014c). Both Dorper sheep and Merino sheep showed only a similarity of 30% in their diets with **Afrikaner cattle** (Botha et al. 2001). Adult Afrikaner bulls generally weigh 820-1090 kg, while cows weigh 450-600kg (Afrikaner Cattle Breeders' Society of South Africa 2018). Afrikaner calves have a relatively small birth mass of 30-35kg (Afrikaner Cattle Breeders' Society of South Africa 2018).

Dorper Sheep

The potential soil disturbance (soil trampling factor) of the Merino sheep is 20-30 percent less than that of the **Angora goat** (de Beer 2016). This emphasises the importance of correctly calculating the stocking rate. When grazing in mixed Karoo veld, 14.6 Merino sheep, will remove the same amount of forage at a similar plant composition as one mature Afrikaner steer grazing on the same type of veld. Similarly, 12.5 Boer goats and one mature Afrikaner steer will remove the same amount of forage (Botha et al. 2001). Generally, grazing a range of species on the same area (multispecies grazing) will result in an efficient utilisation of veld resources, due to differing dietary habits between species (Walker 1994). This means that, when stocking densities are conservative, the impact of grazing will be more evenly distributed across the vegetation community, and should result in vegetation communities that are more resistant, not only to grazing, but also other ecological factors such as drought (Walker 1994). Importantly, however, interspecific competition and dietary overlap will increase with grazing pressure and decrease with plant community diversity (Walker 1994), thus the value of the multispecies grazing technique declines when veld productivity is low as a result of degradation.


Afrikaner Cattle


Boer Goat


Angora Goat


Dorper Sheep

6. Wildlife Ranching

6.1 Introduction

The majority (more than 80% in 1999) of the Karoo belongs to private owners, where sheep and goat farming is the dominant land-use (Dean & Milton 1999). Game ranching is, however, becoming increasingly popular in the Nama Karoo, as it is often considered more profitable than livestock farming, primarily due to the hunting (biltong and trophy), live game auction, and to a lesser extent, ecotourism industries (Cloete et al. 2007). Additionally, there is a growing amount of evidence that suggest that game farms provide a range of ecological and socio-economic benefits compared to livestock farming, particularly in semi-arid areas (Langholz & Kerley 2006; Lindsey et al. 2013). Wildlife ranches can positively impact natural biodiversity as natural areas of habitat are often maintained, and these areas provide suitable habitats for the reintroduction of threatened species (Cousins et al. 2008). Contrastingly, wildlife ranches may negatively affect the conservation of native biodiversity through the persecution of predators to protect valuable game species and mismanagement of the veld (Cousins et al. 2008).

6.2 Economic Considerations

A farm 50 km south of Kimberley had an optimum carrying capacity of 240 LSU for cattle farming, while for game farming the optimum carrying capacity was recalculated at 208 LSU and 512 browser units (BU), due to the different foraging habits of wildlife and cattle (Cloete et al. 2007). Although game ranching can be more profitable per hectare and less susceptible to drought (Sims-Castley et al. 2005) compared to cattle, this is not always the case, and the conversion from cattle farming to game ranching requires a high level of capital investment, which is not always feasible (Cloete et al. 2007).

The most expensive infrastructure investment required for converting from cattle to livestock is likely to be a game fence (usually 2.4 m high) (Cloete et al. 2007). Other than the purchase of wildlife, ranchers should consider the costs of ecotourism facilities, if necessary, bomas, loading facilities and hunting rights for biltong and trophy hunts.

6.3 Recommendations

Similar to livestock farming, regular and effective quantitative monitoring is recommended for game farms. Although, rainfall and game birth & mortality rates are commonly monitored on game ranches, other important factors are often overlooked. Veld condition, the game's physiological condition and genetic diversity of populations should also be monitored annually (Van der Waal & Dekker 2000). Grazing capacity estimates should be continually re-evaluated in terms of rainfall and veld conditions. Sufficient forage must be available for ungulates during critical dry periods between rainfall events (Esler et al 2006). As with livestock farms, periodic rest periods of each paddock, whereby plants are able to complete critical growth and reproduction processes, are encouraged on wildlife and mixed livestock-wildlife ranches (Jooste 1983). If this is not possible, and the farm is practicing continuous grazing, recommended stocking rates should be adhered to, and slight understocking is advised in case of suboptimal rainfall conditions (Skinner 1989), and destocking is advised during drought.

7. Drought Management


Glenneis Kriel

Drought is probably the most important factor limiting the livestock production industry in South Africa (Hoon 1999). Drought management strategies should depend on the prevailing conditions, including economics, availability of forage resources, nutritional requirements of stock, knowledge of the type of drought prevailing, and predictions as to the length of the drought. There are three main categories of drought in South Africa (Hoon 1999):

1. Protein Drought: It is the same as a normal winter/summer dry season with sufficient dry veld (or stubble-fields). Protein is the only nutrient that is deficient.

2. Protein & Energy Drought: The quality and quantity of veld has deteriorated, similar to a normal late dry season when the quality as well as the quantity of veld (or stubble) are a problem. Protein and energy are supplements will be required to prevent large mass and reproduction losses.

3. Total Drought: Total drought situations will vary between the normal late dry season situation and a disaster drought where no roughage from the veld is available. Large stock such as cattle will be impacted sooner than sheep and goats, because the small stock utilise veld more thoroughly and efficiently. For the first phase of a disaster drought, it will therefore be cheaper to maintain sheep and goats.

Drought Management Strategies

1. Sell Animals	*2. Retain animals at a low level of livestock productivity*	*3. Supplementary feeding*
4. A combination of the strategies listed above		

Reducing and fluctuating stock numbers with prevailing rainfall conditions and consequently, the grazing capacity, is a proven long-term drought management strategy, commonly promoted in the arid-areas. However, once conditions fall below a critical threshold, farmers should meet the nutritional requirements of stock with supplement feed. During these conditions, continuing to graze the veld may lead to enhanced degradation, making post-drought recovery more difficult. In fact, Müller et al. (2007) recommend that destocking during drought, and rapid post-drought restocking is not a sufficient strategy for ensuring long-term rangeland productivity in semi-arid regions. Rest periods are considered crucial when vegetation has a low regeneration potential, such as in the Karoo (Müller et al. 2007). Restocking should be a slow and gradual process, whereby stock are restricted from portions of the rangeland to allow the veld to rest, and allow seed production and seedbanks to recover (Nenzhelele 2017).

- Heavy, continuous grazing before a drought is believed to increase the severity of drought by exacerbating drought mortality of grass tussocks and hindering post-drought recovery and seedling establishment (O'Connor & Pickett 1992; O'Connor 1994).
- Cattle usually require supplementary feeding before sheep and goats, as small stock are able to utilise shrubs and other plants more efficiently (Hoon 1999). For the first phase of the drought it is cheaper to retain sheep and goats.
- Drought planning is essential. Ranchers should plan ahead and know what their next step will be should the drought get worse.
- The aim of a feeding strategy should be to optimise the efficiency of utilisation of the available least-cost resources, for example dry veld early on in a drought and supplementary feed later on.
- If the drought is prolonged and livestock have utilised as much of the veld as possible, without the onset of soil erosion, supplements should be provided.
- In most cases, ranchers should use feed as efficiently as possible to maintain animals.
- Old animals or animals with poor reproduction records should be sold first.
- Research has found that animals receiving survival diets daily performed worse and had higher mortality rates compared to animals fed twice or just once a week. This is because less feed provided frequently allows for some animals to ingest far more than others, leading to others starving, while more feed provided less frequently allows all animals a chance to receive enough feed (Hoon 1999).
- Supplementary feeding should start before animals have lost more than 15% of their overall body mass. This does not apply to pregnant females; as large weight loss may lead to abortions.
- Drought fodder crops are crop species that are well-adapted to adverse conditions, such as low rainfall, and make efficient use of available moisture. Drought crops should be fairly drought resistant, have a high carrying capacity, should not have any adverse effects on the animals' health, and should have a high ability to recover after intensive utilisation.

8. Case Studies

8.1 Sustained Heavy Grazing in the Kamiesberg, Succulent Karoo

A study described in Anderson & Hoffman (2007), measured plant community diversity and composition in 0.1 ha sample plots in rangeland grazed at recommended stocking rates and in adjacent rangeland grazed at twice recommended rates for many years. Heavy grazing did not result in the dominance of a few, widespread and weedy species. Additionally, species richness at the 0.1 ha scale was not affected by land use. However, there was a substantial shift away from large woody and succulent shrubs to dwarf shrubs and herbaceous annual and perennial plants in heavily grazed areas. Additionally, a reduction in perennial grass was recorded in rocky habitats in the heavily grazed areas. The increase in ephemeral and herbaceous plants make heavily-grazed areas vulnerable to drought.

8.2 Non-Selective Grazing (NSG) impacts on Nama Karoo soil properties

In this case study (Beukes & Cowling 2003), the non-selective grazing system of short-duration, low-frequency, intensive herbivory by livestock had a positive effect on soil quality. In ungrazed areas, microbial activity was largely restricted to clumps of plants. The grazing system greatly increased microbial activity (and hence nutrient cycling) on bare ground between plant clumps. The grazing system also lowered the organic carbon content of the soil, and improved aggregate formation leading to higher soil stability and infiltration capacity. The authors suggested that these soil changes improved the overall environmental condition of the soil and promote productivity and sustainability.

8.3 Stocking densities and water infiltration

A study (du Toit et al. 2009) conducted at Grootfontein Agricultural Development Institute, 10 km northeast of Middelberg in the Eastern Cape investigated the impact of three rates of stocking (4, 8 and 16 small—stock units per hectare). The area is characterised by Nama Karoo shrubs and grasses. Light trampling of the soil (4 SSU/ha) increased the initial infiltration rate of the soil compared to un-grazed rangeland, but soil infiltration decreased with increasing stocking rates due to increased soil compaction. Low stocking density was found to positively influence all soil parameters measured. It was concluded that stocking density and rotation schemes need to be carefully considered to ensure the sustainable utilisation of arid shrub-/grassland regions by livestock in the Nama Karoo.

8.4 Livestock watering points

Todd (2006) investigated the animal impact around artificial watering points in the Nama Karoo. Plant cover and composition was measured at regular distances from 10 m – 2,200 m from 11 watering holes. Karoo vegetation structure and cover was found to be somewhat resilient to livestock grazing, however plant diversity was not. Vegetation near water points were found to have less species richness compared to areas further away, and most of those plant species that disappeared near water points were considered highly palatable. This loss in species richness was directly attributed to heavy grazing near watering points, which often lead to an increase in alien vegetation and forbs near water points. Those areas further away from water points contained a significantly greater proportion of palatable species. In conclusion, large camps/ paddocks provide a refuge for sensitive, palatable species. The presence of these palatable species is a valuable indicator for monitoring veld condition.

8.5 Rotation & wet season resting in Australia (Ecograze System)

This system, described in Liniger & Critchley (2007), is made up of three fairly equally-sized (±1,000 ha) camps with two livestock flocks / herds rotating between them (Figure 2). Importantly, this system allows all camps to receive four months of wet season rest and recovery in two years out of three. This wet-season rest is divided into two main periods: A.) Early wet season rest commences after the first rains and continues for 6-8 weeks. This period is important for the recovery of perennial grasses; B.) Late wet season rest continues until the end of the wet season, and is important for vegetation recovery and seeding. Each camp is fenced and provided with a water source. This system successfully increased perennial grass cover, and thus improved productivity, animal carrying capacity and increased profit over the long-term. However, as this system requires rotational grazing it incurred moderate investment costs in the form of fencing and water points. A long-term approach was necessary to accommodate the slow rate of change in the environment. Importantly, this system was designed for a region experiencing an average annual rainfall of 500-750 mm, which is greater than long-term annual rainfall for anywhere in the Karoo.

		Paddock A	Paddock B	Paddock C
Year 1	Early Wet	Rest	Graze	Graze
	Late Wet	Graze	Rest	Graze
	Dry	Graze	Graze	Rest
Year 2	Early Wet	Graze	Graze	Rest
	Late Wet	Rest	Graze	Graze
	Dry	Graze	Rest	Graze
Year 3	Early Wet	Graze	Rest	Graze
	Late Wet	Graze	Graze	Rest
	Dry	Rest	Graze	Graze

Figure 2. Layout of the Ecograze system showing the cycle of grazing and rest periods for each camp or paddock (Liniger & Critchley 2007).

Box 2: Summary Case Study recommendations from a sustainable land management view point.	
Case Study	Summary Recommendation
1	Loss of perennial forage plants and an increase in ephemeral plants through grazing in combination with future climate change, will reduce the capacity of vegetation communities to maintain grazing value through environmental fluctuations. With continued plans for landownership redistribution in Namaqualand, and the expansion of communal areas, consideration needs to be given to the implications of sustained heavy grazing for the sustainability of people's livelihoods.
2	Based on the tentative results of this study, any grazing system that leads to an increase in soil biotic activities will improve overall ecosystem condition, and consequently productivity (but not necessarily biodiversity) and sustainability.
3	High stock densities can result in enhanced compaction, which causes reduced infiltration rates, but modest trampling (associated with low stocking rates) can increase infiltration through the removal of the soil crust.
4	Grazing-sensitive species that generally occur away from water points (areas of frequent and intensive grazing and trampling) can be important candidates for monitoring and predicting future changes in a rangeland, as they commonly the first to respond to changes in grazing intensity.
5	In the Ecograze system, the number of stock movements are fixed, but the timing can be adapted according to the recovery state of perennial grasses.

9. Recommendations & Conclusion

Best practice grazing management design should first and foremost incorporate the governmental and agricultural laws. Additionally, the precautionary principle infers that we should choose strategies which involve the least risk. Often degradation and changes in vegetation, such as a loss of palatable species, associated with livestock grazing is not immediately noticeable, thus threats to biodiversity are commonly underestimated and neglected. Monitoring biodiversity and agricultural productivity over the long-term is an important component of sustainable agriculture to ensure that a change in practice has the intended outcome. Specific and clear baseline measurements, with which future measurements can be compared at regular time intervals, should be taken. This is an outcome-based, rather than action-based approach, which allows land practitioners to recognise disturbance and improvement, and thus, adapt and alter their practices as necessary. This includes responding to prevailing climatic and environmental conditions, and the associated natural cycles by implementing adaptive management strategies, such as increasing rest periods or manipulating livestock numbers.

Drought is not uncommon in the Nama Karoo, but because the identification of drought is uncertain, there is often a lagged response in reducing stocking rates (Thurow & Taylor 1999). Drought should be considered in the development of a grazing management plan before such an event takes place. This means that the management strategy should focus on minimising climatic and financial risk, rather than attempting to maximise forage production (Holechek 1996). A grazing management plan that allows for a cushion of "reserve forage" provides farmers with some flexibility in the speed and extent to which they respond to drought (Thurow & Taylor 1999). Furthermore, it is crucial to monitor the extent of use on key vegetation species, as this can be used as a proxy for grazing pressure (Thurow & Taylor 1999). Careful monitoring allows the rancher to rapidly identify and respond to the initial stages of forage deficit (Thurow & Taylor 1999).

Drought years may represent opportunities for farmers to improve veld biodiversity and long-term condition, because established unfavourable shrubs may be killed off, thus allowing space for reseeding and establishment of more favourable species (Esler et al. 2006). During the period of plant reseeding and establishment (following drought-breaking rainfall) livestock should be restricted from the area to prevent trampling and degradation (Esler et al. 2006). Healthy livestock require regular access to drinking water and farmers should consider the quality, quantity, location and seasonality of water sources available for livestock (Koelle et al. 2016). Provided that grazing conditions are stable, livestock that do not have to travel long distances to acquire water, are likely to be in better condition and will cause less soil compaction compared to those which do (Koelle et al. 2016). Contrastingly, however, areas around watering holes often show decreased levels of species richness and a lower proportion of palatable species compared to areas further away from the watering point (Todd 2006). Farmers should therefore aim to limit travel distance to water points, while simultaneously limiting the quantity of water points and carefully considering their location in the landscape. See for example figures 3 and 4:

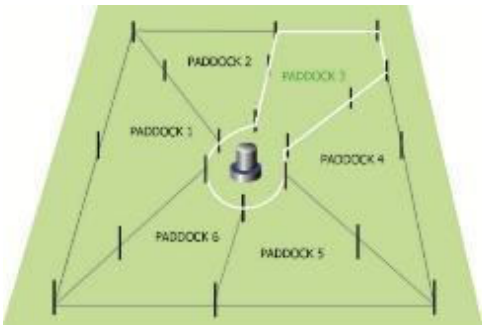

Figure 3. Wagon-wheel pasture layout with centre watering point.

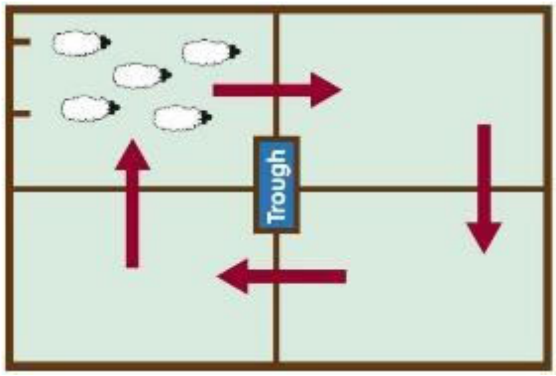

Figure 4. Rotational Grazing schematic.

Veld condition should be consistently monitored, and during dry years, rotational grazing systems should be amended to be more conservative and allow longer rest periods for adequate vegetation recovery (Todd et al. 2009). Good quality rangelands have a suitable coverage of indigenous grasses that are perennial, palatable and productive ("3P grasses") and therefor produce healthy livestock (Liniger & Critchley 2007). Rests of longer than one year have shown to be highly beneficial in the Karoo veld. Additional water points and supplement feeding may also be required during these periods although both may exacerbate damage to the veld either directly, or indirectly by maintaining livestock at densities high enough to damage vegetation during the post-drought regrowth period. Contrastingly, during the occasional very wet years, land owners are encouraged to build up good forage reserves, allowing palatable plants the opportunity to recover and produce seed (Esler et al. 2006). Increasing stocking density during wet periods is not promoted, as this may lead to unsustainable grazing pressure in the future and will not provide vegetation with the opportunity to grow, reseed and establish before drier conditions return. Wet years provide the opportunity to build up fodder reserves of long-lived, palatable, diverse Karoo grasses and shrubs to buffer against future drought conditions (Esler et al. 2006).

Riparian areas are often over-utilised in arid and semi-arid regions, as they usually provide shade, water and high quality forage resources during the rainy season (DelCurto et al. 2005). To prevent degradation associated with trampling and overutilization, these habitats generally respond well to an exclusion of grazing or if grazing is restricted during critical periods (Wyman et al. 2006). The principal method to improve the resilience of the Nama Karoo and mitigate against the threat of climate change is to conserve natural biodiversity, promote the growth of indigenous vegetation, reverse degradation and promote sustainable land management. The importance of landscape connectivity for native biodiversity should be considered. Native plant and animal species should be able to respond to climate change and not become trapped in islands surrounded by unsuitable regions of degradation, thus limiting dispersal and movements (Todd et al. 2009).

Karoo rangelands are naturally heterogeneous, thus plant productivity, composition and diversity are diverse across multiple scales. Continuous grazing practices promote homogeneity through the uniform distribution of livestock across the landscape, which may have a critical impact on native biodiversity and wildlife habitat (Fuhlendorf & Engle 2001). Rotational grazing systems, where patches are grazed and rested at varying times of the year in a mosaic pattern, facilitate heterogeneity, that can enhance biodiversity and wildlife habitat (Fuhlendorf & Engle 2001).

In conclusion, well-managed, sustainable grazing management is compatible with ecological conservation; however, poor grazing management can cause substantial degradation, biodiversity loss across the landscape, as well as have long-term financial repercussions.

References

Afrikaner Cattle Breeders' Society of South Africa. 2018. History. Available from http://www.afrikanerbees.com/Society-History.htm (accessed February 19, 2018).

Anderson PML, Hoffman MT. 2007. The impacts of sustained heavy grazing on plant diversity and composition in lowland and upland habitats across the Kamiesberg mountain range in the Succulent Karoo, South Africa. Journal of Arid Environments **70**:686–700.

Andrew MH. 1988. Grazing impact in relation to livetsock watering points. TRENDS in Ecology & Evolution **3**:336–339.

Beukes PC, Cowling RM. 2003. Non-selective grazing impacts on soil-properties of the Nama Karoo. Journal of Range Management **56**:547–552.

Botha P, Blom CD, Sykes E, Barnhoorn ASJ. 2001. Using dietary overlap to calculate animal ratios on mixed Karoo veld. Karoo Agric **3**:12–17.

Botha W, Mellet W. 2002. Does a high stocking rate pay? Dorper News **61**:1–5.

Brand TS. 2000. Grazing behaviour and diet selection by Dorper Sheep. Small Ruminant Research **36**:147–158.

de Beer EF. 2016. Sustainable Mohair Industry Production Guidelines: Pre-Farm Gate. SA Mohair Growers' Association. Available from http://www.angoras.co.za/application/storage/upload/msa_sustainable_guidelines_20162017_ed_5_english.pdf.

DelCurto T, Porath M, Parsons CT, Morrison JA. 2005. Management strategies for sustainable beef cattle grazing on forested rangelands in the Pacific Northwest. Rangeland Ecology & Management **58**:119–127.

du Toit GN, Snyman HA, Malan PJ. 2009. Physical impact of grazing by sheep on soil parameters in the Nama Karoo subshrub/grass rangeland of South Africa. Journal of Arid Environments **73**:804–810.

du Toit PCV. 2001. Predicting grazing capacities from linepoint survey- and phytomass data. Grootfontein Agricultural Development Institute **3**:26–27.

du Toit PCV. 2003. Estimating grazing capacities for karroid areas. Karoo Agric **6**:1–16.

du Toit PCV, Blom CD. 1994. Diet selection by different small-stock species in the arid Karoo. Karoo Agric **6**:25–27.

Esler KJ, Milton SJ, Dean WRJ. 2006. Karoo Veld - Ecology and Management. Briza press, Pretoria, South Africa.

Farmer H. 2010. Understanding impacts of water supplementation in a heterogeneous landscape. Ph.D. Thesis. University of the Witwatersrand, Johannesburg, South Africa.

Fuhlendorf SD, Engle DM. 2001. Restoring heterogeneity on rangelands: Ecosystem management based on evolutionary grazing patterns. BioScience **51**:625–632.

Hawkins H. 2016, May 7. Holistic Management Literature Review: Part 1. Available from https://www.farmersweekly.co.za/agri-technology/farming-for-tomorrow/holistic-management-literature-review-part-1/ (accessed October 15, 2017).

Herselman MJ. 1992. Hardiness in small stock. Proceedings of the South African Society of Animal Production.

Herselman MJ, Olivier WJ. 2009. Description of a model for the calculation of breeding values for profitability. Pages 80–82 Merino Science. Grootfontein Agricultural Development Institute, Middelburg, South Africa.

Hoffman MT. 1988. The rationale for karoo grazing systems: Criticisms and research implications. South Africa Journal of Science **84**:556–559.

Hoffman MT, Cousins B, Meyer T, Petersen A. 1999. Historical and contemporary land use and desertification. Pages 257–273 in W. R. J. Dean and S. J. Milton, editors. The Karoo, Ecological Patterns and Processes. Cambridge University Press, Cambridge, UK.

Hoffman MT, Cowling RM. 2003. "Nature"s method of grazing': Non-Selective Grazing (NSG) as a means of veld reclamation in South Africa. South African Journal of Botany **69**:92–98.

Holechek JL. 1996. Drought in New Mexico: Prospects and management. Rangelands **18**:225–227.

Hoon JH. 1999. Feeding Management in Drought Years. Proceedings of a joint ZSAP/PAO Workshop, Harare, Zimbabwe.

Koelle B, Slabbert E, Koopman A, Oettle N, Archer E, Kotze D. 2016. Livestock Farming Under Climate Change Conditions. Indigo Development and Change, Nieuwoudtville.

Liniger H, Critchley W. 2007. Where The Land Is Greener: case studies and analysis of soil and water conservation initiatives worldwide. WOCAT - World Overview of Conservation Approaches and Technologies, Stämpfli AG, Bern, Switzerland.

Mucina L et al. 2006. Nama-Karoo Biome. The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia **19**:324–47.

Müller B, Frank K, Wissel C. 2007. Relevance of rest periods in non-equlibrium rangeland systems - A modelling analysis. Agricultural Systems **92**:295–317.

Nenzhelele E. 2017. Long-term impacts of livestick grazing in the Succluent Karoo: A 20-year study of vegetation change under different grazing regimes in Namaqualand. M.Sc. Thesis. University of Cape Town, Cape Town, South Africa.

O'Connor TG. 1994. Composition and population responses of an African savanna grassland to rainfall and grazing. Journal of Applied Ecology **31**:155–171.

O'Connor TG, Pickett GA. 1992. The influence of grazing on seed production and seed banks of some African savanna grasslands. Journal of Applied Ecology **29**:247–260.

Ross JAG. 1995. The effects of sheep grazing on the recovery of Succulent Karoo vegetation. M.Sc.Thesis. University of Natal, Pietermaritzburg, South Africa.

Saayman N. 2016. Basic guidelines to Veld Management - Central Karoo. Info-pack ref. 2016/06. Elsenburg Agricultural Training Institute, Stellenbosch, South Africa.

Salomon M, Cupido C & Samuels I. 2013. The good shepherd: remedying the fencing syndrome, African Journal of Range & Forage Science, 30:1-2, 71-75, DOI: 10.2989/10220119.2013.781064

Scarnecchia DL. 1985. The relationship of stocking intensity and stocking pressure to other stocking variables. Journal of Range Management **38**:558–559.

Snyman MA. 2014a. South African sheep breeds: Merino sheep. Info-pack ref. 2014/022. Grootfontein Agricultural Development Institute, Middelburg, South Africa.

Snyman MA. 2014b. South African sheep breeds: Afrino sheep. Info-pack ref. 2014/013. Grootfontein Agricultural Development Institute, Middelburg, South Africa.

Snyman MA. 2014c. South African goat breeds: Boer goat. Info pack ref. 2014/002. Grootfontein Agricultural Development Institute, Middelburg, South Africa.

Teague R, Provenza F, Kreuter U, Steffens T, Barnes M. 2013. Multi-paddock grazing on rangelands: Why the perceptual dichotomy between research results and rancher experience? Journal of Environmental Management **128**:699–717.

Teague WR, Dowhower SL, Baker SA, Haile N, DeLaune PB, Conover DM. 2011. Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass praire. Agriculture, Ecosystems and Environment 141:310–322.

Thurow T L, Taylor C A. 1999. Viewpoint: The role of drought in range management. Journal of Range Management **52**:413–419.

Todd SW. 2006. Gradients in vegetation cover, structure and species richness of Nama-Karoo shrublands in relation to distance from livestock watering points. Journal of Applied Ecology **43**:293–304.

Todd SW, Milton S, Dean R, Carrick PJ, Meyer A. 2009. Ecological Best-Practice Livestock Production Guidelines for the Namakwa District. Draft 1. Karoo Consortium.

Vorster L. 2017. Current status and impact (2004-2015) of indigenous ungulate herbivory on the vegetation of Sanbona Wildlife Reserve in the Little Karoo. M.Sc. Thesis. University of Cape Town, Cape Town, South Africa.

Walker JW. 1994. Multispecies Grazing: The Ecological Advantage. Sheep Research Journal **Special Issue**:52–64.

Wyman S et al. 2006. Riparian area management: grazing management processes and strategies for riparian-wetland areas. Page 105. Technical Reference TR 1737-20. BLM/ST/ST-06/002+1737. US Department of Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO, USA.