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Quality of two veld types in the Northern Cape as quantified in grazing sheep

by

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Submitted in partial fulfilment of the requirements for the degree

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Declaration

I, Lood Visser, declare that this dissertation for the degree M.Sc. (Agric.) Animal Science: Animal Nutrition at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Signature:.....................

Date:.....................

L. Visser

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Quality of two veld types in the Northern Cape as quantified in grazing sheep

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The purpose of this study was to quantify the nutritive value of two veld types in the Northern Cape and also to identify limitations regarding animal production directly from the natural pasture. The two veld types were identified as Grassveld and Ranteveld. Three sheep were fitted with oesophageal fistulae and allowed to graze each veld type for three days every month for two years. Analysis was done to determine the crude protein (CP), phosphorus (P), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), molybdenum (Mo), *In-vitro* organic matter digestibility (IVOMD), neutral detergent fibre (NDF), acid detergent insoluble nitrogen (ADIN) and metabolizable energy (ME) content of the two veld types. Six sheep fitted with rumen cannulae were allowed to graze each veld type for six days every month for two years. Rumen fluid was collected and analysed for volatile fatty acids (VFA) and rumen ammonia-nitrogen (NH_3-N). Blood was also collected for blood urea nitrogen (BUN) analyses and faecal samples were drawn to test faecal phosphorus and faecal crude protein as nutritional indicators.

For the oesophageally collected samples there were differences between Year 1 and Year 2 for all of the parameters. There was also differences between Grassveld and Ranteveld for all of the parameters. Crude protein was shown to have large seasonal variation in both Ranteveld and Grassveld, with Grassveld having lower CP concentrations for most of the year compared to Ranteveld. The crude protein content was low during winter and was identified as the first limiting nutrient during dry periods. Phosphorus had low concentrations in both veld types with large seasonal variation. The mineral balance of the two camps differed widely with Ranteveld having higher concentrations for Ca, Cu, Mg, Mn, Fe and Zn compared to the Grassveld. Calcium, copper, magnesium and manganese were found in concentrations that were acceptable for most applications

of animal production. There was a deficiency of Zn and Mo in both the veld types. The Fe concentration of both veld types was very high. The calcium concentration of the selected diets was high and caution should be taken to ensure that the high intake levels of calcium through feed and water do not disturb mineral balances in livestock. The IVOMD concentrations for both veld types were similar throughout the trial period. The IVOMD concentration dropped during the dry winter months. The NDF concentrations was higher in the Grassveld than in the Ranteveld for most of the trial period. Acid digestible insoluble nitrogen (ADIN) did not have a seasonal trend and would further lower the nitrogen available to animals throughout the year.

The rumen cannulated animals showed differences between years and veld types for VFA's and rumen-NH_3-N. Total VFA concentration showed seasonal variation with few differences between months. Acetic acid concentrations was high with relatively low concentrations of propionic and butyric acid. Rumen NH_3-N had large seasonal variations. Rumen NH_3-N was low during the dry months and would not support optimal rumen function and animal performance. BUN was shown to be an indicator of diet crude protein. Faecal phosphorus and faecal crude protein was not a reliable indicator of diet phosphorus or diet crude protein content.

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List of Abbreviations

ADF – Acid detergent fibre

ADL – Acid detergent lignin

BUN – Blood urea nitrogen

BW – Body Weight

Ca – Calcium

Ca:P – Calcium to phosphorus ratio

CP – Crude Protein (N x 6.25)

Cu – Copper

DM – Dry matter

DMI – Dry matter intake

DOM – Digestible organic matter

EE – Ether extract

Fe – Iron

IVOMD – *In vitro* organic matter digestibility

Ha – Hectare

K - Potassium

ME – Metabolisable Energy

Mg - Magnesium

MJ – Mega Joule

mm – millimetre

mmol – Milli mol

Mn – Manganese

Mo – Molybdenum

NDF – Neutral detergent fibre

NH_3-N – Ammonia nitrogen

NIRS – Near infrared reflectance spectroscopy

OF – Oesophageal fistula

OM – Organic matter

PPM – Parts per million

R^2 – Coefficient of determination

S – Sulphur

Se - Selenium

SE – Standard Error

VFA – Volatile Fatty Acid

UIP – Undegradable intake protein

Zn – Zinc

Chapter 1

Introduction

The Northern Cape province of South Africa is characterized by low and erratic rainfall and thus large extensive small stock farming operations is one of the major contributors to the economy of this area. The total number of sheep in the Northern Cape in 2013 was 6 174 000 and this contributes to nearly 25.2% of South Africa's sheep population (NDA, 2013). The aim of farmers of this area is to produce lambs ready for slaughter directly from the veld. The reason for this being the long distance from grain producing areas, resulting in uneconomical feedlotting of lambs due to high transport costs of grain and animals. For this reason, farmers rely heavily on the natural pastures to provide sufficient energy, protein and a balanced combination of minerals for growth and production of sheep. Limited data is currently available on the quantity of nutrients of the veld in this area.

The knowledge of quantitative digestion and metabolism has clearly shown that the way toward substantial increases in ruminant productivity is through the balanced nutrient approach that considers the efficiency of the rumen ecosystem and the availability of dietary nutrients post-ruminally (Leng, 1993). The nutritive value of veld and, moreover its ability to support animal production, as well as the role of supplementary feeding in promoting animal production should be studied under realistic and practical conditions (Engels, 1983; De Waal, 1990; DelCurto *et al*., 2000). After shortages have been established a supplementation program must be formulated which is able to provide sufficient nutrients for efficient production and reproduction of animals under extensive conditions (Van Niekerk, 1996).

This study aimed to determine the nutritive value of two environments namely Grassveld and Ranteveld that is used for small stock production in the Northern Cape. The subsequent data will then be used to formulate a supplementary feeding program enabling farmers to maximize growth and production of sheep throughout the year.

The study area was in the arid karoo and Dessert False Grassveld Biome of South Africa (Accocks, 1990). This area was later re-categorised by Mucina *et al.* (2006) as the Bushmanland arid grassland vegetation type. The two habitats that are used for sheep production in this biome are the Grassveld and Ranteveld environments.

The daily quantity of dry matter that is consumed by an animal is a measurement critical to making nutritional interferences about feed and subsequent animal responses (Schneider and Flatt, 1975). No method has been devised by which intake of grazing livestock can be accurately quantified (Cordova *et al.*, 1978). For this reason the intake was estimated using various ranges of intakes determined by authors for sheep under similar conditions (Cook & Harris, 1951.; Cook *et al.* 1962.; Van Dyne & Meyer, 1964.; Langlands & Bowles, 1974.) Three objectives were set to determine the nutritional status of the animals. The first objective determined the qualitative intake and level of selection of specific species at specific times of the year. This was done to quantify the baseline of nutrients that are available. To obtain this objective oesophageally fistulated sheep was used. There are several methods that can be used to help identify which nutrients are limiting the performance of animals. Drawing of hand samples is not effective because of the high rate of selection by sheep (Van Niekerk, 1996). This problem can be overcome using oesophageally fistulated animals. This method has shown that grazing animals particularly sheep and goats, will select feed which has a higher nutritive value than hand drawn samples. (Dudzinski *et al.*, 1973; Zeeman *et al.*, 1984). Mineral analysis of the oesophageal fistula samples will be done and the values compared to that of the NRC (2007).

The second objective was the measurement of rumen fermentation parameters namely, volatile fatty acids (VFA) and rumen ammonia-nitrogen (NH_3-N). This was done by using ruminally cannulated sheep. The level of ammonia-N in the rumen is critical for microbial fermentation. For effective fermentation, the ammonia-N levels should be above a minimum level for prolonged periods especially on fibrous diets, which are slowly fermented. Volatile fatty acids are responsible for 60-70% of the metabolisable energy in ruminants (Van Soest, 1994) and are of great importance for sheep production.

The third objective was the measure of blood urea nitrogen (BUN). This parameter will be measured on the basis that BUN reflects the ammonia-N production in the rumen (Lewis, 1957). Low dietary nitrogen (N) intakes rapidly and significantly lower BUN levels.

Chapter 2

Literature Review

2.1. FEED INTAKE OF SMALL RUMINANTS ON FORAGE DIETS

2.1.1. Introduction

Forage intake is one of the main drivers for animal production. Intake by herbivores are driven by the animals need for nutrients, mainly protein and energy (NRC, 1987; NRC, 2007). There are various factors that influence the level of intake in ruminants (Weston, 2002; NRC, 2007). These factors can be divided into three sub-categories namely: Animal factors, plant factors and quality factors (Hardy *et al.* 1997). There is a great lack of understanding of the intricate relationship between animals and their environment and these effects on the intake of dry matter by animals. A lack of sure ways to predict the intake of grazing ruminants is only exacerbated by the various prediction models, all with different outcomes (Cordova *et al.* 1978).

2.1.2. Animal Factors

Diet selection by sheep is a multifactorial action. This involves sight, smell taste and post-ingestive responses from the forage consumed (Provenza 1995). Du Toit (1998) showed that animal species and breed also has an effect on the ability and rate, at which animals select their diet. Sheep were shown to be able to select diets with a higher nutritive value compared to cattle or hand clipped samples by humans (Dudzinski *et al.*, 1973; Squires, 1980; Zeeman *et al.*, 1984). Zeeman *et al.* (1984) showed large variation in the nitrogen concentration of material selected by different species on Karoo veld. These authors' results are presented in Figure 1.

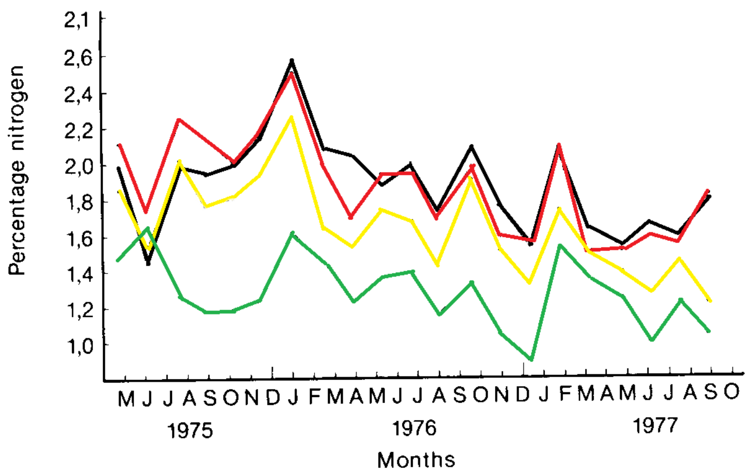

Figure 1 Percentage nitrogen content of material selected by Dorper sheep (Black), Merino sheep (Red), Boer goats (Yellow) and Cattle (Green) on Karoo-veld (Zeeman *et al.,* 1984)

Sheep also select for certain herbage regardless of quality. Legumes are preferred by sheep over grass and this is of great economic importance as the sheep have higher intakes of legumes compared to grass of the same quality (Freer & Jones 1984). This in turn leads to higher live weight gain and production as shown by Freer & Jones (1984). The limitations of physical size and negative feedback of the digestive system also limits intake (Romney & Gill 2000). The two most important factors to consider here are chemostatic or metabolic feedback from the body where hormones and blood metabolites play a role in the feeling of satiety of animals. The second important mechanism is the physical feedback that is controlled by the distention of the rumen. In high forage diets this is often the first limiting feedback response (Fisher, 2002). The voluntary feed intake of animals is also directly linked to the quality of grazing. Animals can only ingest more forage as soon as the earlier ingested forage passes through the gastrointestinal tract to make room for more forage. This makes the ability of the animal to digest food one of the most important factors in determining voluntary feed intake (Hardy *et al.,* 1997).

2.1.3. Plant Factors

Plant factors that affect intake by grazing ruminants can be subdivided into quality of the plant material and the quantity of the material available to the animals (Hardy *et al.,* 1997). The quality of the forage can be affected by the type of plant species Tropical grasses tend to have more stems than temperate grasses. This is due to higher cell wall fractions in the total plant DM. The higher cell wall constituents, lowers passage rates due to slower degradation and break down in the reticulo-rumen environment (Hardy *et al.,* 1997). Temperate grasses tend to have lower cell wall percentages which leads to higher rates of breakdown in the reticulo-rumen. This enables animals to have higher intakes and in turn leads to better production (Hardy *et al.,* 1997). Further differences between C3 and C4 plants can be found in the leaf structure, with the mesophyll cells in C3 plants more loosely stacked than that of C4 plants and with C4 plants that have thicker leaf epidermis (Watson & Dallwitz, 1980). Both of these factors were found to lead to a lower rate of microbial degradation (Watson & Dallwitz, 1980).

Sward structure will also influence the quality of the forage and the level of intake. Sward greenness was found to have a major effect on the quality of the pasture. Sward that is green is often still growing and these parts of the plants have the highest nutritive value. Sward height will affect the stem to leaf ratio. When sward grows higher more stems are present (O'Reagain & Owen-Smith, 1996). Stems have a lower nutritive value compared to leaves (Chacon *et al.,* 1978; O'Reagain & Owen-Smith, 1996). The lower nutritive value leads to lower intakes (Hardy *et al.,* 1997). Sward density also plays a role in total intake per unit of time (Penning *et al.,* 1991). Black & Kenny, (1984) has shown that sword density is positively related to bite size, and feed intake. If the sward density drops below a critical value, animals would spend more energy on grazing than obtaining from the pasture.

Seasonal effects plays a crucial role in the intake dynamics of a grazing ruminant. The highest quality pastures and intake in tropical climates is usually in spring with lower quality and lower intakes during autumn and winter (Hardy *et al.,* 1997).

2.1.4. Quality Factors

Forage quality has been defined in many ways, but mostly in relation to some kind of an animal response, such as intake, weight gain and milk yield or wool growth (Yoana *et al*., 2006) Forage quality has also been estimated from certain plant attributes such as leaf: stem ratio and stage of plant maturity (Dietz, 1970). A high quality food source for a ruminant animal will include the following properties: 1) high palatability of the source with subsequent high intakes, 2) levels of various nutritive components in the correct ratios for use by the animal, 3) high digestibility with nitrogenous and non-nitrogenous compounds in optimal ratios, 4) volatile fatty acid production in the optimal ratios to ensure efficient use and production of energy, 5) adequate minerals, trace-minerals and vitamins and 6) efficient conversion into components needed to sustain the animal body (Dietz 1970).

Anti-quality factors are also an important role player in the intake dynamics of free grazing ruminants (Launchbaugh *et al.,* 2001). Plants have various defence mechanisms that help it deter grazing animals from over utilising it. These anti quality factors leads to negative post-ingestion feedback which limits the further intake by animals. Anti-quality factors can reduce plants digestible nutrients and energy, or yield toxic effects (Launchbaugh *et al.,* 2001). In Figure 2 Launchbaugh *et al.* (2001), illustrates the effect of plant anti-quality factors and the digestive consequences that leads to altered animal performance.

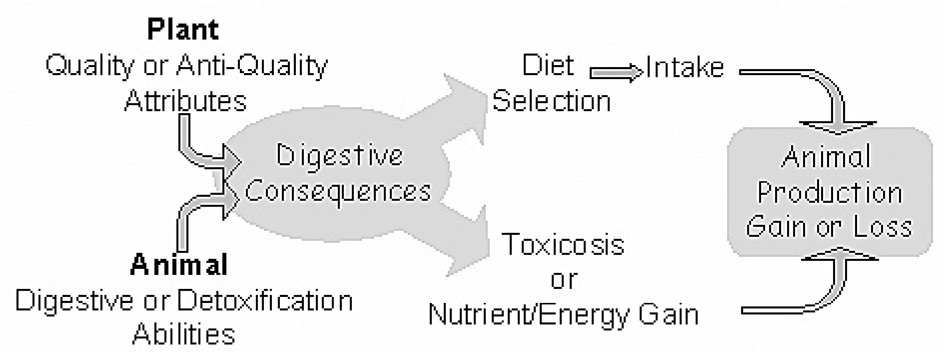

Figure 2 The consequences of ingesting plant anti-quality factors on a grazing herbivore (Launchbaugh *et al.* 2001)

2.1.5 Intake Prediction

Intake measurement on pasture is one of the biggest challenges animal scientists face. The challenge arises from the inability to physically measure the amount of feed refused by the animal as in pen studies (Coleman, 2005). There is currently no precise method with which the intake of a grazing ruminant can be accurately measured. There is always some estimation needed when values for intakes are required giving rise to a lack in accuracy and precision (Coleman, 2005). Burns *et al.* (1992) reviewed several methods for estimating intake in grazing ruminants.

The oldest and most conventional method of predicting intake is the by means of total faecal collection using faecal collection bags (Cordova, 1978). The researcher only needs the total amount of faeces voided and the digestibility of the forage to make intake calculations of the animal (Coleman, 2005). The process however is cumbersome with large amounts of faeces collected each day. The bags are troublesome to fit and the loss of some of the faeces is also a possibility (Adegosan *et al.,* 2000). Furthermore animals will need to be collected at least twice daily to collect the faeces this might have further effects on the natural grazing patterns of the animals (Lippke, 2002).

The use of indigestible markers dosed to animals in known quantities is probably one of the most widely used techniques to determine intake by grazing animals (Coleman, 2005). The concept of the marker technique is that the indigestible markers are fed to animals until an equilibrium is reached. The amount of marker fed to the animal per unit of time is equal to the amount of marker excreted per unit of time (Colemean, 2005). For this technique to be effective the following conditions must be met: The marker must be completely indigestible or must have a known digestibility, the marker must be excreted evenly throughout the day with no fluctuations in excretion patterns and the marker must not interfere with rumen activity (Coleman, 2005). Markers that are commonly used include chromium sesquioxide (Cr_2O_3), rare earth elements such as Ytterbium (Yb), and long chain alkane waxes (C_{32} and C_{36}), (Coleman, 2005; Decruyenaere, 2009). The daily dosing of animals might have an influence on the grazing patterns of livestock, but this has to a large extent been corrected by the development and use of controlled release devices that releases accurate doses of marker to the animals daily (Berry *et al.,* 2000; Ferreira *et al.,* 2004). For the markers technique to be implemented successfully the collected forage used for digestibility studies must be similar to that grazed by the animals (Decruyenaere *et al.,* 2009). If the sample of the pasture used for digestibility predictions is not the same as the diet selected the intake prediction will be biased (Decruyenaere *et al.,* 2009). Hand plucked samples will not be representative of the pasture consumed by animals (Engels, 1983; De Waal, 1990). The use of oesophageal fistulated animals to obtain representative samples can be used but is disliked in regards to animal welfare and may alter the grazing behaviour of animals (Coates *et al.,* 1987; Jones & Lascano, 1992).

Table 1 and Table 2 shows research results on voluntary intake levels of sheep grazing different types of pasture from 1951 to 2009 (Cordova, 1978; Decruyenaere *et al.* 2009). The data in Table 1 and Table 2 shows the daily forage intake on a metabolic body weight basis ($BW^{0.75}$) and as a % of the animals' body weight. There is also a column extrapolating the data to determine the predicted forage intake of a 60kg animal. There is a large variability between the lowest and the highest levels of intake. The lowest levels of intake of only 31.4g/kg$BW^{0.75}$ was recorded by Langlands & Bowles, (1974) on native pastures in Australia. This level equates to an intake of only about 1.13% of body weight or 680g for an animal weighing 60kg. The highest intake was recorded as 109.2g/kg $BW^{0.75}$ by Arnold & Dudzinski (1967) on *Phalaris* and *Trifolium* pastures. This equates to an intake of about 3.92% of body weight resulting in a 60kg animal consuming 2.35kg of pasture on a DM basis. Minson (1990b) showed animals had a lower mean daily intake (50.8 g/kg $BW^{0.75}$) when fed tropical grasses compared to temperate grasses (67.3 g/kg $BW^{0.75}$). This could explain the lower values recorded in Table 1, (Cordova, 1978), compared to the higher values in Table 2, (Decruyenaere *et al.,* 2009).

Table 1 Ranges in daily voluntary feed intake on a dry matter basis by grazing sheep adapted from Cordova (1978)

Reference	Type of forage	Originally expressed unit	Intake g/kg.BW$^{0.75}$	Pasture intake as % body weight	Predicted pasture intake for a 60kg animal (kg)
Cook & Harris, 1951	Winter desert range	lb/100lb	57-88.2	2.04 - 3.17	1.23 - 1.90
Fels & Rossiter, 1959		lb/100lb	36.3	0.78	1.3
Pearce & Vercoe, 1961	Mature *Lolium rigidum*	lb/100lb	44.1	1.58	0.95
Cook *et al.,* 1962	Poor and good Desert range	lb	65.7 - 83.3	2.36 - 2.99	1.42 - 1.80
Van Dyne & Meyer, 1964	Dry annual summer range	lb	43.5 - 58.0	1.56 - 2.08	0.94 - 1.25
Arnold *et al.,* 1964	Perennial and annual pastures	kg	39.7 - 78.3	1.42 - 2.81	0.86 - 1.69
Arnold & Dudzinski, 1967	*Phalaris* and *Trifolium* pastures	kg	48.5 - 109.2	1.74 - 3.92	1.05 - 2.35
Langlands, 1968	Improved pastures	kg	39.3 - 52.4	1.41 - 1.88	0.85 - 1.13
Wilson *et al.,* 1971	Native annual grassland	kg	53.2 - 62.9	1.91 - 2.26	1.15 - 1.36
Wilson et al., 1971	Improved annual and native pastures	kg	42.3 - 59.5	1.52 - 2.14	0.91 - 1.28
Langlands & Bowles, 1974	Native pastures	kg	31.4 - 46.7	1.13 - 1.68	0.68 - 1.01
Donnely *et al.,* 1974	*Trifolium* pastures	kg	49.8 - 70.5	1.79 - 2.53	1.07 - 1.52
Arnold, 1975	*Phalaris* and *Trifolium* pastures	kg	34.3 - 56.1	1.23 - 2.02	0.74 - 1.21

Table 2 Ranges in daily voluntary feed intake on a dry matter basis by grazing sheep adapted from Decruyenaere *et al.* (2009)

Reference	Type of forage	Originally expressed unit	Intake g/kg.BW$^{0.75}$	Pasture intake as % body weight	Predicted pasture intake for a 60kg animal (kg)
Jarige *et al.,* 1986	Temperate grasses	DM, g/kg BW$^{0.75}$	66.0 - 90.0	2.37 - 3.23	1.42 - 1.94
Pasha *et al.,* 1994	Temperate grasses	DM, g/kg BW$^{0.75}$	78.0 - 91.0	2.80 - 3.27	1.68 - 1.96
Delaby & Pecatte, 2003	Temperate grasses, first cycle	DM, g/kg BW$^{0.75}$	65	2.33	1.4
	Temperate grasses, second cycle	DM, g/kg BW$^{0.75}$	79	2.84	1.7
	Temperate grasses, third cycle	DM, g/kg BW$^{0.75}$	58	2.08	1.25
Delaby *et al,.* 2007	Temperate grasses, spring	DM, g/kg BW$^{0.75}$	62	2.23	1.34
	Temperate grasses, early summer	DM, g/kg BW$^{0.75}$	80	2.87	1.72
	Temperate grasses, late summer	DM, g/kg BW$^{0.75}$	83	2.98	1.79
	Temperate grasses, fall	DM, g/kg BW$^{0.75}$	74	2.66	1.6
	Temperate grasses, spring	DM, g/kg BW$^{0.75}$	67	2.41	1.44
	Temperate grasses, early summer	DM, g/kg BW$^{0.75}$	79	2.84	1.7
	Temperate grasses, late summer	DM, g/kg BW$^{0.75}$	81	2.91	1.75
	Temperate grasses, fall	DM, g/kg BW$^{0.75}$	81	2.91	1.75
Decruyenaere *et al.* 2009	Temperate grasses	OM, g/kg BW$^{0.75}$	44.2 - 85.4	1.59 - 3.07	0.95 - 1.84
	Temperate grasses	OM, g/kg BW$^{0.75}$	52.7 - 79.1	1.89 - 2.84	1.14 - 1.71
	Temperate grasses	OM, g/kg BW$^{0.75}$	41.9 -83.6	1.51 - 3.00	0.90 - 1.80
	Temperate grasses	OM, g/kg BW$^{0.75}$	56.4 - 79.1	2.02 - 2.84	1.12 - 1.70
	Temperate grasses	OM, g/kg BW$^{0.75}$	64.3 - 87.3	2.31 - 3.13	1.39 - 1.88
	Temperate grasses	OM, g/kg BW$^{0.75}$	52.7 - 104.7	1.89 - 3.76	1.13 - 2.26
	Temperate grasses	OM, g/kg BW$^{0.75}$	70.9 - 83.1	2.54 - 2.99	1.53 - 1.79
	Temperate grasses	OM, g/kg BW$^{0.75}$	63.3 - 98.3	2.27 - 3.53	1.36 - 2.12

Animal intake can be determined by studying the grazing behaviour of the animal. Intake is the product of three parameters: grazing time, bite rate and bite size (Rook *et al.,* 2004). The grazing time and bite rate can be measured by visual observation (Rook *et al.,* 2004). The presence of the observer however could alter the grazing behaviour of animals. It is therefore necessary to accustom the animals to the human observer (Agreil *et al.,* 2004). Quantifying the bite size can also lead to predicted intake bias (Decruyenaere *et al.,* 2009).

There were various attempts to predict intake and digestibility from diet characteristics (Moore, 1994). Tilley & Terry (1963) proposed an *in vitro* process to determine the digestibility of forages. The Tilley & Terry (1963) method however has some limitations as it is unable to accurately predict the digestibility of some tropical grasses (Nelson *et al.,* 1975). Freer and Jones (1984) suggested that digestibility could be used as a predictor for intake. Estimates of intake in relation to digestibility however is poor and correlations of -.30 to 0.78 was found in literature (Minson,1990a; Moore & Coleman, 2001).

Moore *et al.,* (1999) showed a uniform relationship between digestible organic matter (DOM) intake and crude protein. In Figure 3 it can be seen that as soon as crude protein (CP) drops below 80g/kg there is a strong linear reduction in the organic matter intake. Under these condition ruminal microbes may be nitrogen (N) limited relative to energy and the supplementation of N will lead to increased OM intake (Moore *et al.,* 1999).

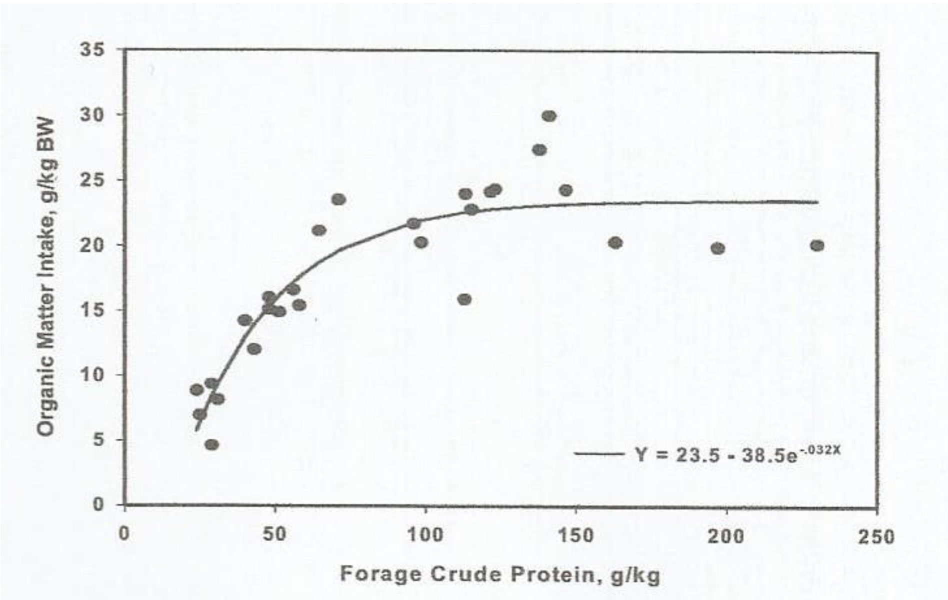

Figure 3 Response of organic matter intake to increases in crude protein concentration of forages fed alone (Moore *et al.,* 1999)

Plant cell wall constituents that have been linked to intake include: neutral detergent fibre (NDF) (Mertens, 1987; Meissner *et al*., 1991), acid digestible fibre (ADF), (Cilliers & Van der Merwe, 1993) and acid digestible lignin (ADL) (Pietersen *et al.,* 1993). Meissner *et al.* (1991) showed that intake was generally limited by NDF intake when diet NDF levels were above 55% to 60%, but not for lower levels. Mertens (1987) proposed that NDF intake ≈ 1.2% of body weight for diets producing maximum levels of 4% fat corrected milk. Meissner & Paulsmeier (1995) developed an empirical equation for different animal species and forage types. The intake of non-lactating ruminant species fed on various diets could be predicted with the same relationship from the ratio between *in vitro* digestibility of organic matter (IVDOM) and NDF. When forage intake falls below the IVDOM/NDF predicted value minus the error of estimate then there are other factors than cell wall induced factors limiting intake (Meissner & Paulsmeier, 1995). Meissner and Paulsmeier (1995) showed that the higher the IVOMD : NDF ratio is the higher OM intake will be. Thus higher intake and higher animal production could be expected at higher IVOMD : NDF ratios.

Poppi (1996) argued that near infrared reflectance spectroscopy (NIRS) was the intake prediction method of the future and that large databases could be established by collection of spectra and intake values as trials were conducted. The use of NIRS to correctly predict the crude protein and digestibility of forage was shown by Lyons & Stuth (1992). Using these digestibility values together with faecal indices collected from NIRS will help animal scientist predict animal intake in relatively short periods of time (Decruyenaere *et al.,* 2009). Boval *et al.* (2004) used this concept very successfully to directly predict intake during trials where steers in confinement were fed a harvested forage diet. Although the use of NIRS has various limitations including the development of robust calibrations and the need of an independent set of values for validation of calibrations, this technique has potential to markedly reduce the turnaround time for intake predictions (Decruyenaere *et al.,* 2009).

2.2. OESOPHAGEAL FISTULA TECHNIQUE

2.2.1. Introduction

A major limitation when studying the nutritive value of natural rangeland is the ability to collect a representative sample of the diet the animals select (Soder *et al.,* 2009). The quality of material selected by animals can be of a higher nutritive value than that of the pasture on offer. To obtain a representative sample becomes more difficult as the spatial heterogeneity and paddock size increase (Coates & Penning, 2000).

There are two basic approaches to obtain representative samples from grazing. The first is a hand collection of forage by the researcher in such a manner as to mimic the selection of different species as selected by the animal (Wallis de Vries, 1995; Decruyenaere *et al.,* 2009). The high selection rate of grazing animals complicates the selection of grazing by hand. The researcher will not be able to exactly mimic the selection of the animal which subjects this method to an unknown bias. The method can be successful if there is little species variation and the grazing is of a homogenous nature, coupled with an elaborated stratified sampling approach (Langlands, 1974; Wallis de Vries, 1995). The inability of hand cut samples to represent the diet of grazing animals was well documented in South Africa (Brendon *et al.*, 1970; Engels, 1983; De Waal, 1990), Namibia (Van Schalkwyk, 1978) and Botswana (Pratchett *et al.*, 1977).

The alternative method of obtaining representative samples of the pasture consumed is the use of surgically altered animals by means of oesophageal or rumen fistula (Coleman, 2001). Oesophageal fistulated animals are preferred over rumen cannulated animals because of the time consumed to evacuate and wash the rumen and to avoid the abnormal physiological conditions associated with rumen evacuation (Holenchek *et al.*, 1982). Rice *et al.*, (1971) found differences, both botanically and chemically when comparing rumen fistula grab samples to oesophageal fistula samples of bi-cannulated sheep. This was attributed to the chemical alteration of nutrients in the rumen.

The most accurate representation of the diet of a free-ranging ruminant was given by samples collected from oesophageal fistula (OF) animals (Holenchek *et al,.* 1982). The OF technique is not new and was used as early as 1855 on horses and in 1939 the first ruminants was fitted with OF (Van Dyne & Torrel, 1964). Since the inception of the technique many alterations has been made to improve the collection procedures and equipment (Mcmanus *et al.*, 1962; Brendon & Short, 1971; Breen & Hunter, 1976; Olson & Malechek, 1987; Raats *et al.*, 1996).

Primary disadvantages of OF were surgery, salivary contamination, rumen content contamination, incomplete collection and obtaining a representative sample in a large pasture (Holenchek *et al.,* 1982). Proper care and maintenance of OF animals is also costly and time consuming (Coates & Penning, 2000).

2.2.2. Saliva contamination

Saliva contamination of the extrusa was studied extensively by Marshall *et al.,* (1967); McKay *et al.,* (1969) and Wallace *et al.,* (1972). They found the effect of saliva contamination on oesophageally collected samples to be minimal. Wallace *et al.* (1972) and Holenchek *et al.,* (1982) highlighted that care should be taken when using OF extrusa samples to analyse for phosphorus, as saliva contamination can increase the level of phosphorus. Wallace *et al.* (1972) found that ash was the primary contaminant of samples that were collected with OF and that the level of contamination varied with plant types and season of grazing. Hart, (1983) proposed that the practice of rinsing of OF samples should be stopped as this raised the detergent fibre and lignin concentrations and decreased the crude protein and in *vitro dry* matter digestibility. This is most likely due to the leaching of nutrients. Alternatively Hart, (1983) proposed that OF samples should be squeezed gently to remove excess saliva.

Mineral concentrations of pasture can be determined from OF samples. Little (1975) found that extrusa samples can be used to determine S, Cu and Mo concentrations. Pinchak *et al.* (1990) conversely found that OF samples cannot be used to determine Na, P, K, and Cu but indeed to determine Ca, Mg and Zn concentrations. Mineral enrichment of the extrusa was found to mostly affect the P, Na and K concentrations of the diet (Mayland & Lesperance 1977). The raised P, Na and K levels in the extrusa is due to the high levels of these minerals present in the saliva of ruminants (Pinchack *et al.,* 1990). Although phosphorus levels are elevated by the OF sampling procedure, it still remains the most accepted method for sampling pasture forage phosphorus for chemical analysis (Karn, 1995).

2.2.3. Sample numbers

Using three animals over three days would give optimal results for collecting oesophageal monsters (Bredon & Short, 1971). Although three animals over two days would theoretically be sufficient if all samples were usable (Bredon & Short, 1971). Botanical and chemical analyses of samples require different numbers of samples to be similarly precise. Botanical samples are more variable than chemical samples indicating a greater number of botanical samples needed for the same precision (Harniss *et al.,*1975). In order to sample most of the dietary chemical constituents to within 10% of the mean with 95% confidence six or fewer animals will be needed (Van Dyne & Heady,1965; Torell *et al.,* 1967).

2.2.4. Drying of oesophageal fistula (OF) samples

The drying of OF samples can lead to a significant change in the chemical analysis of the sample consumed. Burrit *et al.* (1988) reported that the lignin content of samples collected in Brazil were artificially elevated by 31-93% when the samples were oven dried at 40˚C compared to samples that where freeze dried. No change in fibre content was noted for freeze- vs. oven drying. In a second experiment Burrit *et al.,* (1988) compared freeze-, air- and oven drying. Both oven- and air drying elevated the levels of lignin and hemicellulose significantly. The IVOMD was significantly lower for the air- and oven dried samples with the biggest effect being on plants with phenolic compounds. Papachristou & Nastis (1994) found that oven-dried fistula samples produced artificially increased levels of neutral detergent fibre and lignin, while the *in vitro* organic matter digestibility was underestimated in comparison with freeze-dried samples. Burrit *et al.,* (1988) concluded that the best method for drying OF samples was by the freeze drying method. This method leads to more accurate nutritional information. The differences between the drying methods are most likely due to non-enzymatic browning of extrusa during oven- and forced air drying processes compared to freeze-drying (Burrit *et al.,* 1988). The non-enzymatic browning reaction is due to the polymerization of sugars and amino acids into a brown complex that contains 11% protein and has the same physical and chemical properties as lignin (Burrit *et al.,* 1988).

2.3. RUMINAL LIQUOR AS INDICATOR OF NUTRITIONAL STATUS

2.3.1. Ammonia-N

Rumen ammonia-N has been used as a qualitative reference to understand the adequacy of the rumen environment for microbial activity on fibrous carbohydrates (Hoover, 1986). The basis for the strategy to use rumen ammonia-N as a quantitative measure for rumen function is associated with the fact that rumen ammonia-N is the preferred nitrogen source for the growth of fibrolytic microorganisms (Russell, 2002). Rumen ammonia-N concentration represents the balance between the formation of ammonia-N in the rumen, utilization by rumen bacteria, metabolism in the rumen wall, absorption into the portal vein and passage into the omasum (Van Soest, 1994). Ammonia-N is produced in the rumen by the metabolism of proteins, peptides, amino-acids, amides, urea, nitrates and some other non-protein nitrogen (NPN) sources (Van Soest, 1994).

For efficient fermentation of fibrous diets the ammonia-N level must be above a minimum level for prolonged periods of time. The proposed minimum levels of ammonia-N (NH_3-N) for maximum growth of rumen microbes is between 2mg/100ml and 5mg/100ml (Satter & Roffler, 1977; Slyter *et al.,* 1979). Leng (1990) suggested that the optimal concentration for rumen ammonia-N was 6-10 mg/100ml. Detmann *et al.* (2009)

showed that optimal NDF degradation rate was achieved at a rumen ammonia-N level of 8mg/100ml. Perdok *et al.,* (1987) found that cattle had the highest dry matter intake of rice straw when rumen ammonia-N levels reached 20mg/100ml. These results are shown in Figure 4.

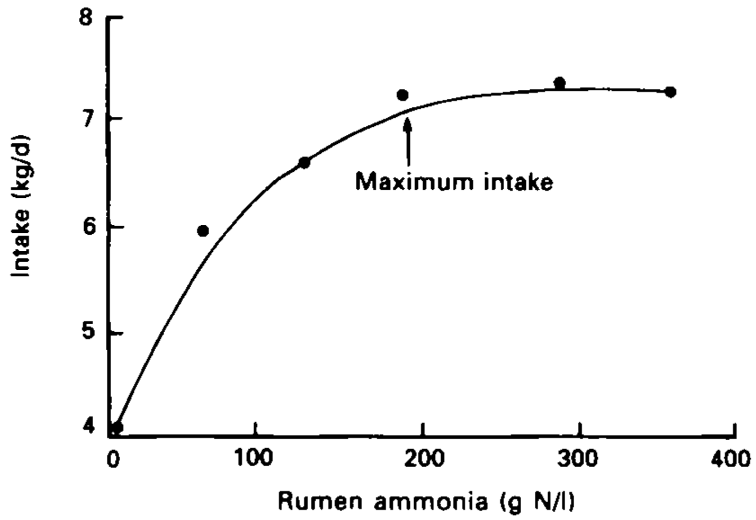

Figure 4 The effects of rumen ammonia-N concentration on the intake of rice straw by cattle. The ammonia levels were adjusted by infusing urea into the rumen (Perdock *et al.,* 1987)

Detmann *et al.* (2009) also showed that optimal levels of dry matter intake of low quality *Brachiaria decumbens* hay was achieved at a rumen ammonia-N level of 15mg/100ml. The differences between the estimates for optimal NDF degradation and highest levels of DMI was believed to be due to a more suitable metabolisable protein: metabolisable energy ratio for animal metabolism (Detmann, *et al.,* 2009).

2.3.2. Volatile fatty acids

Volatile fatty acids (VFA's) are produced as end products of microbial fermentation in the rumen and account for between 50 and 70% of digestible energy intake in sheep (Annison *et al.,* 2002). In animals that are fed adequately the molar proportions of the individual VFA's are largely affected by the type of diet. Diets high in water soluble carbohydrates (concentrate diets) lead to higher molar proportions of propionate. Diets that consists mostly of high roughage has higher acetate proportions (Annison *et al.,* 2002).

Topps & Elliot (1964), studied the rumen fermentation patterns of Blackhead Persian-sheep on a variety of low CP diets. These authors found total VFA concentrations ranged from 2.89 to 9.33 mmol / 100ml of rumen liquor. Both digestibility and protein content of the ration had a significant effect on the concentration of volatile fatty acids in the rumen liquor. Protein content of the diet probably influenced the latter through controlling the rate of ruminal fermentation. Molar proportions of acetic acid varied from 59.7% to 69.3%, propionic acid from 21.2% to 29.6%, and butyric and other volatile fatty acids from 7.6% to 16.3%. Protein content of the diet had no significant effect on the composition of the volatile fatty acid mixture, but organic matter digestibility was inversely related to the proportion of acetic acid in the total volatile fatty acid mixture.

Thomas & Rook (1981), suggested that diets consisting of only forages would give rise to levels of acetic acid in the range of 65-74% with 15-20% propionic acid and 8-16% butyric acid. Thomas & Rook (1981), also characterised high fibrous more mature forages as those that will give rise to high concentrations of acetic acid (>68%) with low levels of propionic and butyric acid. Younger forages would give rise to lower levels of acetic acid (64-68%) with higher levels of propionic and/or butyric acid.

The microbial protein production can be directly affected by rumen propionate levels. Corbett (1987), suggested that when rumen acetate : propionate levels are above 3:1, the supply of readily available energy limits microbial protein synthesis in the rumen.

2.4. BLOOD METABOLITES AS NUTRITIONAL INDICATOR

2.4.1 Blood Urea Nitrogen (BUN)

The use of BUN levels to indicate the level of nitrogen in the feed of ruminants was suggested by Lewis (1957). The basis was that the BUN levels were correlated to ammonia-N production in the rumen. Egan and Kellaway (1971) found blood serum urea levels to be a realistic predictor of nitrogen utilisation in sheep. The protein intake of sheep was also correlated with blood serum urea levels by Nolan *et al.,* (1970). Preston *et al.,* (1965) found a close relationship between protein intake and BUN levels in growing-finishing lambs. Stevens *et al.,* (2004) also found a positive correlation between diet CP an blood serum nitrogen levels when animals were fed high nitrogen containing forages. Torrel *et al.* (1974) confirmed that BUN levels increased as the diets' protein increased. Increased BUN levels were also correlated to higher weight gains and a higher lambing percentage. Torrel *et al.,* (1974) confirmed that there was no significant effect on BUN levels due to sampling time or animal age. Individual animal effects within the same age group did have a significant impact. Valencia *et al.* (2001) also pointed out that breed effects can have a significant impact on the BUN levels collected.

BUN levels can however increase under conditions of starvation or if animals are on a low nitrogen diet due to the catabolisation of body protein (Leibholz, 1970).

2.5. FAECAL PARAMATERS AS NUTRITIONAL INDICATOR

2.5.1. Phosphorus

Faecal excretion of phosphorus is partitioned into three fractions: Firstly, phosphorus of dietary origin, unavailable for absorption; secondly, P of endogenous origin that is excreted under normal conditions; and thirdly phosphorus of endogenous origin which is excreted to maintain homeostasis (Spiekers *et al.,* 1993). The main pathway of endogenous phosphorous (from saliva, undigested microbial debris, intestinal cell walls and digestive secretions) excretion is through faecal matter. Bravo *et al.* (2003) found that about 85% of the P excreted in the faeces was from endogenous origin and the remaining 15% was from undigested and unabsorbed dietary constituents. A further finding by Bravo *et al.* (2003) indicated that as the forage concentration of the diet increased the saliva secretion increased with subsequent higher levels of P found in the faeces. Faecal P concentration is more likely an indicator of the animals' diets than that of the animals P status (Read *et al.,* 1986b). The total collection of an animals faecal output would be the only reliable measure to estimate total phosphorus intake. Grant *et al.* (1996) showed that faecal phosphorus concentrations in cattle showed a very distinct seasonal pattern. The highest faecal P output was during the wet season with a sharp decline during the dry season. Grant (1989) suggested that faecal P levels of below 2.2g/kg suggested a dietary deficiency and that supplementation was required. Faecal P concentration levels between 2.2 and 3.5g/kg were shown to be normal in cattle. Belonje & Van den Berg (1983) found a remarkably constant relationship between the phosphorus in the diet and the phosphorus in the faeces for grazing sheep. Louvandini & Vitti (1996) also confirmed a linear regression (R^2 = 0.95) for the diet phosphorus concentration and the faecal phosphorus concentration.

2.5.2. Crude protein

Nunez-Hernandez *et al.* (1992), found that faecal nitrogen concentration was more closely related to the nitrogen balance of the animal than other faecal indicators.

Hakkila *et al.* (1988), found that faecal P concentration was positively correlated with the protein concentration of the diet consumed. Hakkika *et al.* (1988) found an R^2 = of 0.86 between faecal P concentration and dietary nitrogen concentration and postulated that faecal P could be used to make management decisions on the supplementation of protein to ruminants. Grant (1989) also suggested the use of faecal crude protein to make management decisions. Grant (1989) proposed a faecal CP level of 65g/kg as a minimum, under which deficiencies would occur in cattle. Crude protein concentration levels of 65-100 g/kg would be considered as normal in cattle. Below the concentration of 65g/kg CP indicated a need for protein supplementation in cattle and above 100g/kg CP indicated that supplementation should be decreased. Peripolli *et al.* (2011) studied 58 conventional metabolism trials, carried out with sheep fed 27 forages and found that the faecal nitrogen excretion estimated forage intake with an R^2 = 0.73, conversely faecal nitrogen estimated organic matter digestibility with R^2 = 0.36.

2.6. SPECIES SELECTION

2.6.1. Seasonal trends in plant selection by sheep

Grazing animals have the opportunity to select their diets and many factors influence their choice on a daily basis. Leigh & Mulham (1966) found that animals were able to select their diets from plants that make up only 1 percent of the available forage under semi-arid grazing conditions. Where animals are allowed to graze freely they often tend to select more leaf material than available in the total forage on offer. Sheep have a higher selection intensity compared to cattle which enables them to obtain forage of a higher nutritive value compared to cattle grazing the same pasture (Engels *et al.,* 1978: Arnold 1981).

Du Toit (1998) found that there were only minor differences in the diets selected between Dorper and Merino sheep in three different areas of the Karoo. The diets of the sheep however differed significantly between seasons. In the Arid Karoo Du Toit (1998) found that in the spring sheep focused on annuals and ephemeral plants with a high selection intensity. In the summer the sheep selected mainly grass which made up about 20 percent of the plant cover but contributed up to 60 percent of the diet. During the autumn and winter the diets contained up to 80 percent Karoo shrubs.

Chapter 3

Materials and Methods

3.1. EXPERIMENTAL UNIT

3.1.1. Location

The study area was on the farm Lovedale in the Kenhardt district in the Northern Cape province of South Africa. The farm is situated about 160km west of Kenhardt and 40km south east of Pofadder. Co-ordinates are 19˚- 44'0.57" E, 29˚- 18'58.8" S. The elevation is 975m above sea level.

3.1.2. Climate

The long term annual rainfall on Lovedale is presented in Figure 5. The average rainfall over the past 11 years was 138 mm. With the lowest minimum recorded in 2004 as 49.5 mm, and a total of 255 mm the highest recorded in 2006. Figure 5 shows the variation in rainfall from year to year. The high variability between years is due to the fact that thunderstorms are responsible for the largest portion of rainfall and this leads to very unpredictable and inconsistent rainfall.

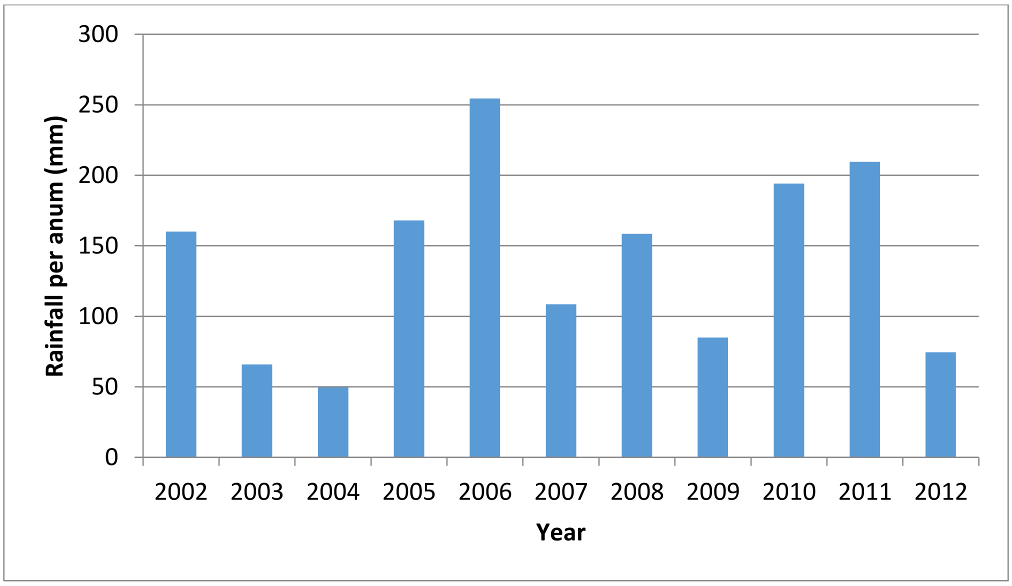

Figure 5 Annual average rainfall for Lovedale from 2002 to 2012 (Visser, 2013)

Average rainfall for each month is given in Figure 6. The maximum rainfall was recorded from January to April with more than 66% of the total annual rainfall in that period. This period is the hot wet season. The dry season usually stretches from May to December. Only about a third of the total rainfall occurs in this period. The dry season can be split into two sub-seasons, the cold and dry season from May to August and the hot and dry season from September to December.

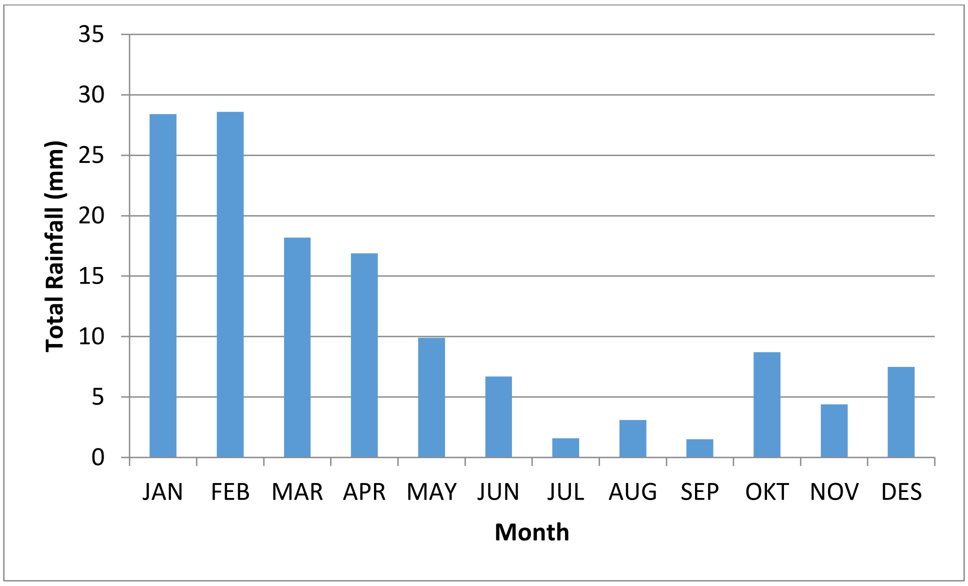

Figure 6 Mean monthly rainfall for Lovedale from 2002 to 2012 (Visser, 2013)

The rainfall distribution during the trial period was very similar to the long term average monthly rainfall patterns. In Figure 7 it can be seen that the highest rainfall occurs during the hot wet-season that stretches from January to April. Small amounts of rain was recorded during the winter of 2011 and 2013.

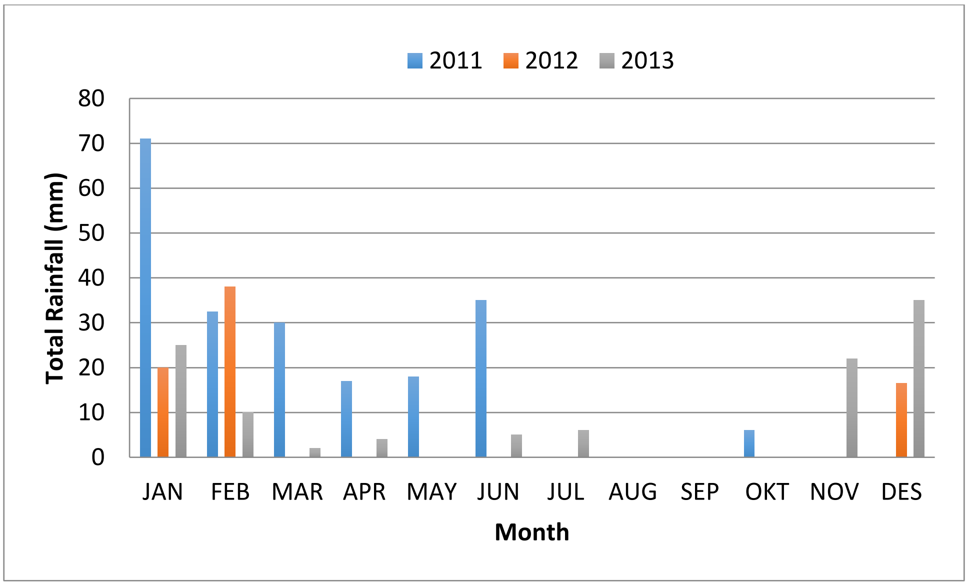

Figure 7 Monthly rainfall for the year prior to the trial (2011) and the two years of the trial 2012 and 2013 (Visser, 2013)

The average temperature of the region varies greatly from summer to winter with average minimum temperatures for July dropping as low as 4˚C and average maximums for January reaching up to 34˚C. Figure 8 shows the average maximum and minimum temperatures for the various months over a 10 year period. Temperature extremes are found during the peak of the winter season with temperatures dropping below 0˚C and temperatures during the hot-wet season easily reaching 40˚C.

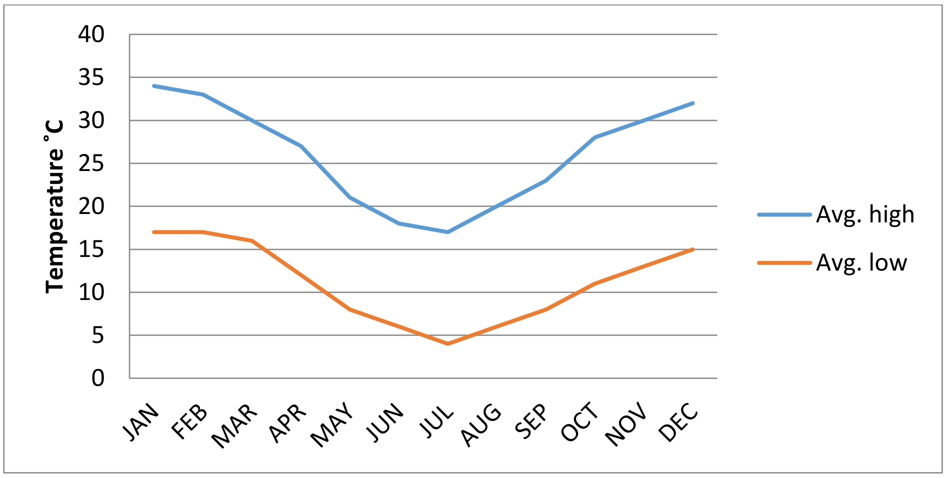

Figure 8 Average high and low temperatures for the study area from 2000 to 2010

Peel *et al.,* (2007) described the climatic zone of the trial location as the Warm Desert Climate zone. This climatic zone is characterized by low annual rainfall that is seasonal with high summer temperatures. In Figure 9 shows the distribution of the climatic zones of Africa with the location of the study area highlighted.

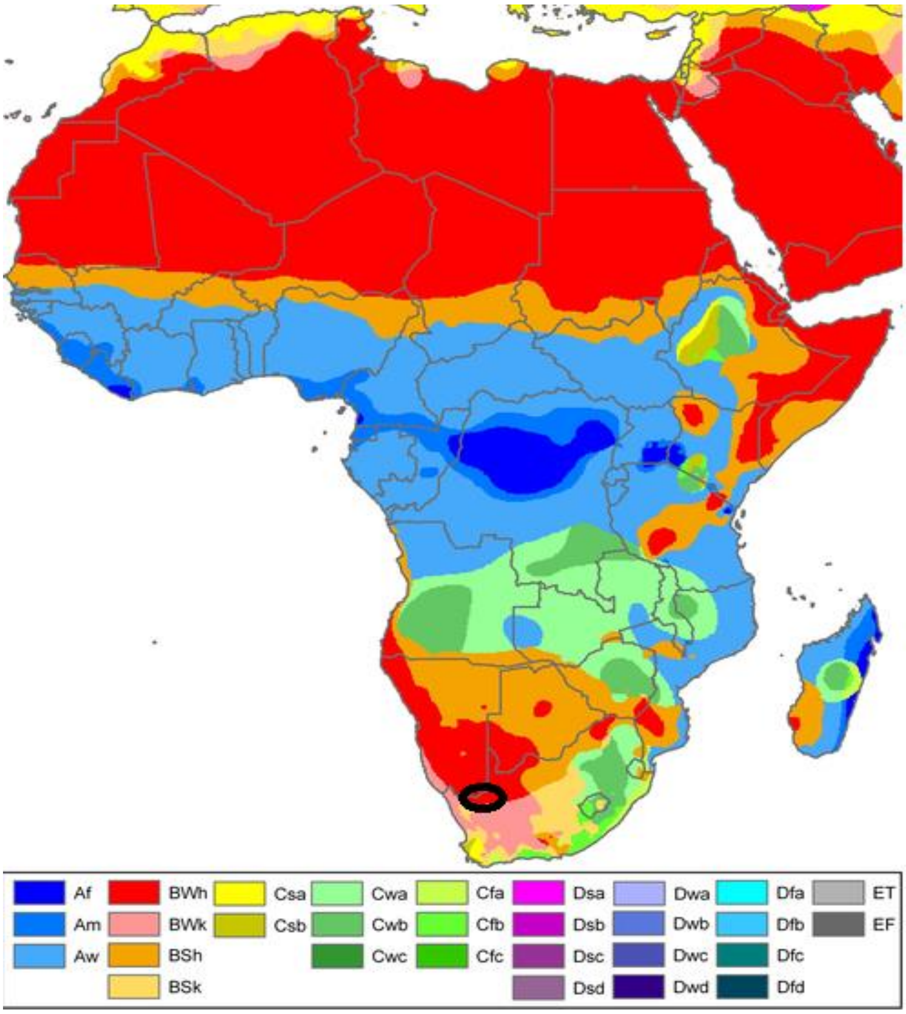

Figure 9 The climate map of Africa indicating the study area in the Warm Desert Climate (BWh) zone (Peel *et al.*, 2007)

3.1.3. Vegetation

The study area is in the Desert False Grassveld Biome of South Africa (Accoks, 1990). This area was later re-categorised by Mucina *et al.* (2006) as the Bushmanland Arid Grassland Vegetation Type. On the property two distinct veld types occur and the sample area was divided into the two veld types. The first type is Ranteveld, as described by Vlok *et al.* (2005). Rantevelt has only a sparse woody tree and tall shrub component present and if present, it is mostly restricted to south-facing slopes. This habitat occurs on ridges and hills where the shale derived soils are very shallow. The vegetation consists mostly of a sparse cover of small shrubs and compact leaf-succulents (Vlok *et al.,* 2005). The second is Grassveld as classified by Mucina *et al.,* (2006). Grassveld is found on extensive plains with slightly sloping topography sparsley vegetated with white grasses (*Stipagrostis* species) giving this vegetation type the character of semidesert. In places low shrubs of *Salsola* species breaks up the vegetation structure. In years of abundant rainfall rich displays of annual herbs can be expected (Mucina *et al.,* 2006).

In the Ranteveld species like *Salsola aphylla, Salsola tuberculata, Salsola glabrescens,Galenia fruticosa, Eriocephalus ericoides, Psilocaulon absimile, Rhigozum trichotomum, Oropetium capense, Enneapogon desvauxii, Stipagrostis obusta* and *Stipagrostis ciliate* are found and represents the majority of the plant biomass.

The Grassveld veld type is dominated by *Stipagrostis obusta, Stipagrostis ciliate* and *Stipagrostis uniplumis* with *Rhigozum trichotomum* occurring in clumps on low lying areas and on sparsely vegetated flats. The sample site was well rested for two years and not overgrazed previously resulting in veld in good condition. The *Stipagrostis* species are very palatable and indicate veld in a good condition. These grass species also bind soil and prevents soil erosion from both wind and water (Van Oudtshoorn, 1991).

Palmer & Ainslie (2002) mapped the rangeland production of South Africa. Figure 10 shows the potential production of the various regions in South Africa. From Figure 7 it can be seen that the potential production for the vegetation of the experimental site is < 0.5 tons of DM per hectare per year.

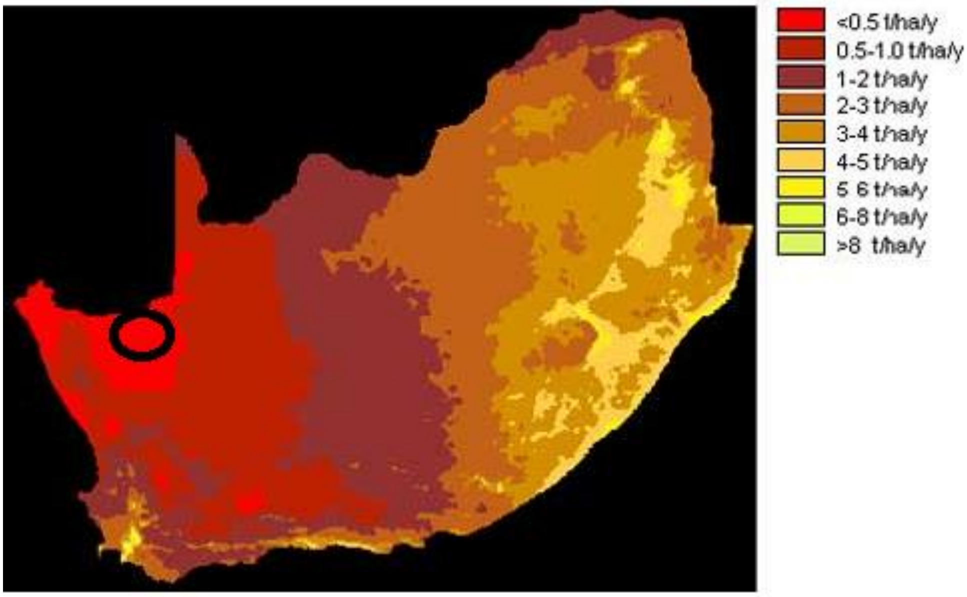

Figure 10 Rangeland production in South Africa (Palmer & Ainslie, 2002)

3.1.3. Water properties

The water analysis for the Grassveld and Ranteveld are shown in Table 3.

Table 3 Water analysis of the drinking water of the two camps used during the trial (mg/L)

	Grassveld	Ranteveld
Chloride as Cl (mg/L)	442	90
Sulphate as SO_4 (mg/L)	234	101
Fluoride as F (mg/L)	2.9	3.6
Nitrate as N (mg/L)	59	4.1
Sodium as Na (mg/L)	279	135
Potassium as K (mg/L)	14.8	3.8
Calcium as Ca (mg/L)	180	51
Magnesium as Mg (mg/L)	40	18
Boron as B (mg/L)	0.884	0.542
Copper as Cu (mg/L)	<0.010	<0.010
Iron as Fe (mg/L)	<0.025	0.464
Mercury as Hg (mg/L)	0.001	0.001
Zinc as Zn (mg/L)	0.139	0.054
Total dissolved solids (mg/L)	1252.724	407.561

The water of the Grassveld showed high levels of nitrates present in the water. The level of nitrate in the water amounted to 261 mg/L when the N present in the sample was converted to nitrate. These levels were cited to have adverse chronic effects on non-pregnant and pregnant ruminants (Department of Water Affairs and Forestry, 1996). Casey and Meyer (1996) noted that water with nitrate levels between 200-400 mg/L could lead to chronic effects such as restlessness, frequent urination, dyspnea, cyanosis associated with methemoglobinemia and decreased feed and water intake in non-pregnant ruminants. These nitrate concentrations of 200-400mg/L could even lead to acute effects in pregnant ruminants including acute methemoglobinemia (Casey & Meyer, 1996). The water in the Grassveld was also relatively high in sulphur, although these levels would not have adverse effects on animals (Casey & Meyer, 1996). The high levels of sulphur could have antagonistic effects on the absorption of copper and selenium (Spears, 2003).

The water in the Ranteveld was suitable to be used as drinking water for livestock (Casey & Meyer, 1996).

3.1.4. Stocking rate

The recommended grazing capacity of the area is 36ha/LSU, or 6ha/SSU (Vorster, 1986). Two camps of nine hectares each were constructed, one in each biome, Grassveld and Ranteveld. The camps were rested for a full growing season to ensure that there was sufficient DM available for the trial period and to simulate typical farming conditions.

The camp size was determined in the following manner:

$$Camp\ size = \frac{Grazing\ days}{365\ x\ Carrying\ capacity}$$ (Undersander *et al.*, 2002)

Grazing days = Number of animals x Number of days per month x Months per year

Rumen cannulated animals = 6 animals x 6 days x 12 months = 432 grazing days

Oesophageal fistulae animals = 3 animals x 3 days x 12 months = 108 grazing days

Total grazing days = 432 + 108 = 540 days

$$Camp\ size = \frac{540}{365\ x\ 6}$$

= 8.876 ha.

The camps were constructed to be a total of 9 ha each with sides of 300m x 300m. The placement of camps was done a minimum of 1 km away from any fence or watering point to ensure that there were no unnatural effects such as overgrazing or unnatural disturbances due to roads or pipelines.

3.1.5. Method of camp utilisation

Two different groups of animals were used to collect data during this trial. The first group was the 3 oesophageal fistulated sheep. These sheep were kept in small camps at the homestead in times when sampling was not undertaken. During sampling times the sheep were moved to the sampling camps. The sheep were only in each sampling camp for 3 days per month. The sheep were moved to alternative camps where sampling continued for 3 days. After the collection (total 6 days) period the sheep were taken back to the homestead in order for the fistula to be cleaned and to receive the needed service and attention until the following sampling date.

The second group of sheep was six ruminally cannulated animals. These sheep were used to determine VFA concentration and rumen-NH_3-N concentration on the two different veld types. The sheep were kept in each camp for a total of 6 days with sampling occurring on days 5 and 6. This allowed for sufficient time for the animals to adapt to the natural grazing conditions. In times when sampling was not done the animals were kept in a small camp around the homestead and the animals were supplemented with lucerne when natural vegetation was deemed insufficient.

3.2 OESOPHAGEALY FISTULATED SHEEP (OF)

3.2.1. Method

The animals that were identified to be fitted with oesophageal fistulae were raised on the natural veld on the farm Lovedale. The animals were weaned at an age of 4-5 months weighing at least 25kg. This was important so that the animals could learn to select a diet representing a diet similar to that of sheep under normal farming conditions (Provenza & Balph, 1987). Approval for this projected was granted by the Research Ethics Committee of the University of Pretoria (Ref: ECO34–12). Doctor Gerhard Harmse fitted the animals with oesophageal fistulae as prescribed by Booyse *et al.,* (2009). The stoppers and spatula were made with PVC. A 6mm stainless steel rod was attached to the spatula with a thin copper sir clip and the rough edges smoothed out with Pratley Putty™. The stopper was pulled down with the use of a stainless steel wingnut that held the spatula and plug firmly in place for times when sampling was not needed. The animals where kept under surveillance for a further 14 days until all the wounds healed properly and the stoppers fitted snugly.

The sample collection bags were made from tough canvas material and made to fit around the neck of the sheep. At the bottom the collection bag a portion of 80% shade cloth was stitched in to allow some of the excess saliva to drain away (Roodt, 2012).

Animals were moved from home to the sampling paddocks. Once in the paddock the fistulae plugs were removed and animals were fitted with the collection bags. The animals were then set loose on the paddocks and were allowed to graze the area freely for ± 30 minutes.

3.2.2. Sampling Periods

Once a month (every four weeks) the animals were allowed to graze the sample area. On the first day the animals would be allowed to graze one of the two camps, either Grassveld or Ranteveld. Three days later the animals were taken to the alternative camp. This was switched every month. The reason for the 3 day waiting periods was to coincide with the sampling of the rumen cannulated animals.

3.2.3. Sampling Procedures

Animals were moved to the trial camps early in the mornings. All of the animals were checked to ensure proper fitment of their OF. The animals were allowed to freely graze the camp for three days. On the morning of the third day the animals were herded into a small handling facility. The animals OF plugs were removed and the animals were fitted with the collection bags. The animals were then allowed to graze freely for about 30 minutes before the collection bags were removed and the OF plugs were replaced. This procedure was repeated later in the afternoon.

3.2.4. Sample preparation

At the end of the sampling period the sample bags were removed. The bags were gently squeezed to force out the excessive saliva through the 80% shade cloth. The fresh samples were then subdivided into smaller manageable portions if needed. The morning and afternoon samples were pooled. The samples were placed into plastic bags and transported back to the homestead were they were frozen at -25˚C.

The samples were transported in their frozen state in a chest freezer back to the University of Pretoria's Nutrilab. The samples were kept in a frozen state until they were freeze dried as suggested by Burrit *et al.* (1988). The dried samples were milled to pass through a 1mm sieve before further lab procedures took place.

3.3 RUMINALLY CANNULATED SHEEP

3.3.1. Method

The animals that were to be fitted with rumen cannulae were raised on the farm Lovedale. Doctor Gerhard Harmse performed the operations and inserted the rumen cannulas according to guidelines set by the Research and Ethics Committee of the University of Pretoria (Ref: ECO34-12). The cannulas that were inserted were made by Bar Diamond Inc.™. The inner diameter of the cannula was 5cm with the outer diameter being 12cm. After the operation the animals were cared and treated for 14 days until fully healthy.

The animals were kept around the homestead during periods when sampling and adaptation was not done. The cannulas were inspected and cleaned once a week to ensure that they fitted tightly.

3.3.2. Sampling Periods

Samples were taken once a month (every four weeks) for a period of two years. Animals were taken to the experimental paddocks 6 days before sampling. This was done to ensure rumen clearance and to simulate the grazing pressure that will be found under realistic farming conditions. Animals were kept in the veld with sufficient water. The animals were brought in on the last day and ruminal liquor samples were drawn three times on the 6th day.

3.3.3. Sampling Procedures

Before the animals were moved to the experimental camps they were checked for any signs of illness or disease. The animals were moved to the sampling camps and allowed to graze the camps for 6 days. On day six the animals were collected at 7am, 12pm and at 5pm. At the first collection period rumen fluid, faecal grab samples and blood from the jugular vein was collected. At 12pm and 5pm only rumen fluid and faecal grab samples were collected. The animals were allowed to graze and had access to water between collection times. The blood was collected from the jugular vein by venepuncture with a green cap vacutainer from Pathcare™ laboratories and kept at temperatures between 5 and 22˚C. The blood samples were then centrifuged at the homestead and sent to Pathcare™ laboratories in Upington were the blood was tested for blood serum urea nitrogen (BUN). The faecal grab samples were pooled for each sheep on day 6 and frozen. The faecal samples were transported in a frozen state to the Nutrilab at the University of Pretoria. The parameters that were tested included crude protein (CP) and phosphorus (P).

For rumen fluid sampling the stopper of the Bar Diamond Inc.™ ruminal cannula plug was removed from the outer cannula which remained fitted in the rumen fistula. Due to the dry nature of the stomach contents it was impossible to suck rumen liquid up through a syringe. Equal portions of stomach contents were removed by hand from the caudal, ventral, anterior and posterior of the rumen. The contents were then placed in four layers of cheese cloth and squeezed gently so as to release ruminal fluid. The solid portion of the samples were discarded. The samples were collected in a plastic cup before being measured off into 30ml subsamples. The subsamples were immediately placed in a 150ml plastic container with a sealable lid already containing the correct volume of preservative. The one set of 30ml subsamples were then preserved in 5ml of 50% H_2SO_4

for rumen ammonia-N-nitrogen (NH_3-N) analysis. Another 30ml subsample was preserved with 5ml of 25% H_3PO_4 for rumen volatile fatty acid (VFA) analysis. The three subsamples that were collected throughout the day were then pooled into one sample for each sheep. The samples were frozen and stored for further analysis by the Nutrilab at the University of Pretoria.

3.4. DETERMINATION OF AVAILABLE FORAGE

The determination of the amount of forage available was done to ensure that the animals still have sufficient forage to graze so as to retrieve a representative sample of the grazing under similar commercial farming conditions. The method used in this instance was the clipping, drying and weighing method.

Ten plots of 1m x 1m were selected at random for each of the sampling paddocks. Once the plot was laid out all of the available forage in the plot was cut down at a height of 3-5cm and placed into brown paper bags. The bags were then oven dried for 24 hours at 50˚C. The contents of the bags where then weighed. The 10 bags represented an area of $10m^2$. The forage dry matter per hectare was then calculated using the following equation: Available Forage DM = Dry Weight of $10m^2$ cuttings X 1000. (Harmoney *et al.,* 1996).

3.5. SPECIES SELECTION

The selection of various species of shrubs and grass was noted during the trial. At four stages representing the four seasons (spring, summer, autumn and winter) of the year. The OF animals were followed when grazing and the forage species selected were noted.

3.6 DETERMINATION OF RESULTS

3.6.1. Lab Procedures

Laboratory analyses were done at Nutrilab, Department of Animal and Wildlife Sciences, University of Pretoria. Oesophageal fistula samples were freeze dried and analysed in duplicate for DM (procedure 934.01 AOAC, 2002), CP was analysed using Leco analysis (procedure 968.06 AOAC, 2002), EE (procedure 920.39 AOAC, 2002), ADF (Goering & Van Soest, 1988), NDF (Van Soest *et al.*, 1997), ash (procedure 942.05 AOAC, 2002), IVOMD (Tilley & Terry, 1963) calcium, magnesium, copper, iron, manganese, zinc (Giron, 1973) and phosphorus (procedure 965.17 AOAC, 2002).

Rumen NH_3-N (Broderick & Kang, 1980) was determined on the solution of rumen fluid preserved with 5ml of 50% H_2SO_4. Volatile fatty acid analysis was carried out on the solution preserved with 5ml of 25% H_3PO_4 according to the procedure described by Webb (1994).

3.6.3. Statistical analyses

Data were analysed statistically with the Proc Mixed model, (Statistical Analysis System 2015) for the average effects. Means and standard error were calculated and significance of difference ($P<0.05$) between means was determined by Bonferroni test (Samuels, 1989).

The linear model used is described by the following equation:

$$Y_{ijkl} = \mu + T_i + J_k + M_l + S_j + TJ_{il} + TM_{il} + JM_{kl} + TMJ_{ikl} + e_{ijkl}$$

Where Y_{ijkl} = variable studied during the period

μ = overall mean of the population

T_i = effect of the i^{th} treatment

J_k = effect of the k^{th} year

M_l = effect of the l^{th} month

S_j = effect of the j^{th} sheep

TJ_{ik} = effect of the ik^{th} interaction between treatment and year

TM_{il} = effect of the il^{th} interaction between treatment and month

JM_{kl} = effect of the kl^{th} interaction between year and month

TMJ_{ikl} = effect of the ikl^{th} interaction between treatment, year and month

e_{ijkl} = error associated with each Y

3.6.4. Hypothesis

H_0: There is no difference between Grassveld and Ranteveld for certain qualitative parameters collected by oesophageal fistula and rumen cannula samples between different months and years.

H_1: There is a difference between Grassveld and Ranteveld for certain qualitative parameters collected by oesophageal fistula and rumen cannula samples between different months and years.

H_0: Faecal crude protein and faecal phosphorus cannot be used to predict diet quality in Grassveld and Ranteveld for different years.

H_1: Faecal crude protein and faecal phosphorus can be used to predict diet quality in Grassveld and Ranteveld for different years.

H_0: Blood urea nitrogen cannot be used to predict diet quality in Grassveld and Ranteveld.

H_1: Blood urea nitrogen can be used to predict diet quality in Grassveld and Ranteveld.

Chapter 4

Results and discussion

4.1. FORAGE AVAILABILITY

The dry matter that was available to the animals during the trial period was determined 8 times over a two year period for each veld type. The results are shown in Table 4.

Table 4 Dry matter available on Grassveld and Ranteveld cut at a height of 5cm above ground during different months for the trial period (kg/ha)

	Grassveld	Ranteveld
March 2012	907.5	785.3
June 2012	824.6	820.7
October 2012	758.6	720.8
January 2013	690.5	706.5
March 2013	865.4	810.6
June 2013	780.5	735.8
October 2013	702.6	697.2
January 2014	870.9	1012.5
Average	801.4	786.2

The DM availability of the two paddocks were taken at specific times coinciding with the monitoring of species selection. Both trial camps were found to have an available forage DM of below 1000kg.ha^{-1}. This is in accordance with Figure 10, Palmer & Ainslie, (2002) who indicated that the forage production per hectare would most likely be <0.5 tons.ha^{-1} per year.

According to Allden, (1962) when forage DM availability drops below 3360 kg.ha^{-1} there is a constant increase of feeding time per day and consistent decrease of DM ingested per hour. Allden (1962) indicated that when there is a pasture availability of about 1000kg.ha^{-1} on a DM basis the feeding time of the animal would be about 8-9 hrs.day^{-1}. This is comparable with what is seen in practice on these large farming units. Animals also walk great distances to obtain enough forage in order to sustain themselves when DM production per hectare is low (Cook *et al.,* 1962).

The available forage calculation for this trial was difficult to determine given the large extent of the trial paddocks (9ha each). Another shortcoming is the ability to accurately strip the parts of the plants that sheep will readily consume, especially in the Ranteveld with the various Karoo shrubs on offer and the woody nature of the plants.

4.2. SPECIES SELECTION

The species selected by the OF animals during the sample collection periods was noted for each veld type. The species selection recording was done at four intervals each year for both 2012 and 2013. The results were grouped in the four main seasons and is shown in Figure 11.

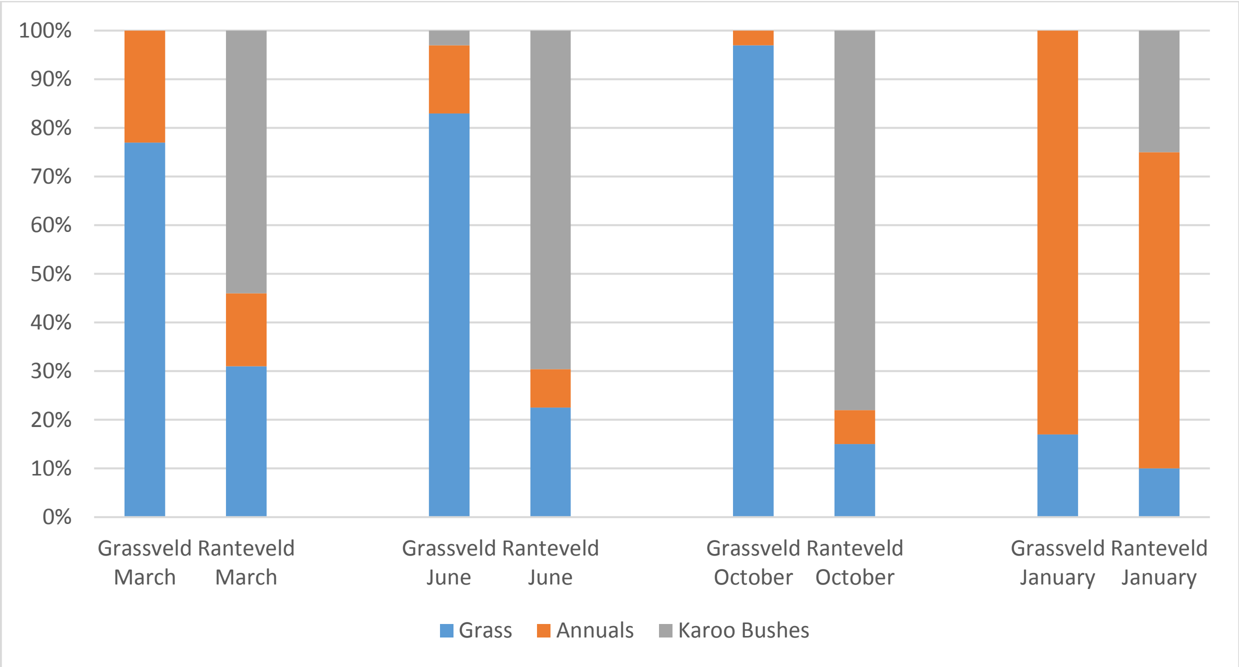

Figure 11 Seasonal trends in diet selection of oesophageally cannulated sheep grazing Ranteveld and Grassveld in the Northern Cape

There was great variation in the selection of forage by the animals during different seasons. During the latter part of summer (March) sheep selected mostly grass species like the *Stipagrostis* species in Grassveld. In Ranteveld the diet consisted of a fairly equal mix of karoo type bushes and grasses like *Stipagrostis obusta* (Kortbeen Boesmangras) and a few annuals including *Schmidtia kalihariensis* (Suurgras) and *Enneapogon desvauxii* (Agtdaegras). The grass component was not very strong in Ranteveld and the available grasses where limited.

During the mid-winter (June) there were almost no annuals left in Grassveld. The animals did not have much choice but to select the *Stipagrostis* species which were still available. In Ranteveld the animals relied more heavily on the karoo bushes, especially those of the *Salsola* species like *Salsola tuberculata* (Koolganna), *Salsola glabrescens* (Rivierganna) and *Salsola calluna* (Rooilootganna).

During the late winter (October) the choice was limited to the *Stiptagrostis* species in Grassveld. Ranteveld still gave a reasonable amount of choice to the animals to graze. Species like *Galenia fruticose* (Van Wyksbos), *Eriocephalus ericoides* (Kapokbossie), *Psilocaulon absimil* (Asbos), *Rhigozum trichotomum* (Driedoring) and *Oropetium capense* (Dwarf grass /Haasgras) were grazed in combination with the *Salsola*-

species. There were still some annuals like *Schmidtia kalihariensis* (Suurgras) but the animals did not select heavily in favour of them.

The January sampling period was after good rains. This led to a large germination and growth of annual plants in both camps. In Grassveld annuals were grazed almost exclusively with plants like *Enneapogon desvauxii* (Agtdaegras), *Schmidtia kalihariensis* (Suurgras) and *Tribulus pterophorus* (Duwweltjies). This high selection of annuals gives insight into the unusually high protein values recorded for February of year 1. In Ranteveld there was also a shift towards annuals but some of the karoo shrubs like the *Salsola* species were still palatable and selected by sheep.

The results that were obtained were in good comparison to the results obtained by Du Toit, (1998) on the Carnarvon and Grootfontein experimental farms. Animals under normal ranging conditions will have a strong tendency to select the more palatable species with a higher nutritive value. This places farm owners under pressure to ensure proper management of the camps with highly palatable species. Some practical aspects of veld management for the trial area will be discussed in Chapter 5.

4.3. OESOPHAGEAL FISTULA EXTRUSA

The results obtained from the oesophageal fistula extrusa are discussed below. The mineral, protein and energy contents of the extrusa were tabled. These tables are presented together with two graphs, the first indicates the various average values of the nutrient under discussion for the two trial years combined within a month. Standard deviations are shown on these graphs. The second graph indicates the average level or concentration of the variable nutrient under discussion with guidelines indicating the nutritional needs of animals at various levels of DMI (NRC, 2007). NRC (2007) values were used as a guideline as these are the norms most often used in South African animal science studies and in the South African animal feed industry.

The needs of a 60 kg mature ewe in mid lactation with a milk production of 0,58 kg/day at dry matter intake (DMI) levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day were used as guidelines (NRC, 2007). The typical ewe in these farming conditions is a 60 kg Dorper ewe, with a single lamb and a milk production of 0.58 kg/day and normal DMI levels (2.68% of BW) as given by the NRC (2007) tables. The depressed intake was set at % of body weight after taking into consideration the previous work of Cordova (1978), Minson (1990b) and Decruyenaere *et al.,* (2009). Table 1 and Table 2 shows the DMI intake levels of grazing sheep ranging from 1.13 - 3.92% of body weight. The average intake of tropical grasses at a value of 50.8 g/kg $BW^{0.75}$ as shown by Minson (1990b) equates to an intake level of 1.095 kg of DM for a 60 kg ewe. This equals a dry matter intake of 1.85% of body weight. The reason for the depressed intake is that these animals in the extensive farming areas of the Northern Cape could be subjected to lower intakes based on low DM availability, large distances to move between feed and water or due to other animal, plant and quality factors.

4.3.1. Crude Protein (CP)

The crude protein results obtained from the oesophageally fistulated sheep are presented in Table 5.

Table 5 The crude protein percentage on a dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae.

	Grassveld		Ranteveld	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2(±SD)**
March	9.65^{a} (0.638)	8.70^{a} (0.664)	12.32^{b} (1.645)	10.96^{ab} (0.831)
April	6.88^{a} (0.487)	5.31^{a} (0.551)	9.60^{b} (1.142)	10.19^{b} (1.037)
May	3.84^{a} (0.759)	4.46^{a} (1.085)	8.75^{b} (0.765)	10.36^{b} (0.482)
June	3.91^{a} (0.419)	3.76^{a} (0.380)	8.35^{b} (1.253)	9.01^{b} (0.880)
July	6.25^{b} (3.293)	3.54 (0.124)	10.11^{c} (3.823)	7.23^{b} (0.282)
August	5.13^{a} (0.972)	4.17^{a} (0.563)	7.36^{b} (3.006)	7.29^{b} (0.562)
September	3.11^{a} (0.086)	3.96^{ab} (0.222)	10.22^{c} (1.741)	5.74^{b} (0.344)
October	3.77^{a} (0.457)	3.54^{a} (0.062)	9.02^{c} (0.837)	6.86^{b} (0.698)
November	3.04^{a} (0.154)	4.11^{a} (0.238)	7.88^{b} (1.378)	12.37^{c} (0.552)
December	4.06^{a} (0.670)	10.00^{c} (0.193)	6.69^{b} (0.306)	6.93^{b} (0.701)
January	3.79^{a} (0.364)	9.66^{b} (0.551)	10.76^{b} (2.309)	13.55^{c} (1.593)
February	17.01^{d} (2.755)	8.34^{a} (0.148)	11.93^{b} (1.745)	14.76^{c} (1.022)
Average	5.87^{a} (4.039)	5.80^{a} (2.529)	9.42^{b} (2.320)	9.60^{b} (2.912)

^{abcd} Row means with different superscripts differ significantly ($P<0.05$)

There was great variation between camps as well as between months within a camp. The highest crude protein recorded for Grassveld was for February year 1 at 17.01% CP on a DM basis. In Ranteveld the highest crude protein value of 14.76% was recorded for February of year 2. This high value can be attributed to the green flush of fresh young grass after the high amount of rainfall during the end of January and beginning of February as shown in Figure 7. The highest crude protein levels always followed on periods of high rainfall in the preceding months (Cronjé 1990). Large seasonal effects are seen with the highest crude protein levels found during the summer months and the lowest during the winter where frost and low soil moisture levels restrict active plant growth. These results were very similar to results reported by Engels (1983); De Waal (1990) and Roodt (2012). Ranteveld had a lower drop in crude protein with crude protein dropping to its lowest point 5.74% in September of year 2 compared to Grassveld with a lowest point of 3.04% in November of year 1.Grassveld had a relatively low variation between the two trial years for crude protein with differences between the two years recorded only for July, December, January and February. Ranteveld on the other hand had larger variation within the same month between years. Significant differences between years were recorded for July, September, October, November, January and February for Ranteveld. During year 1, Grassveld with the higher grass component had lower concentration for crude protein compared to Ranteveld for all the months except for February where Grassveld had a higher crude protein compared to Ranteveld. This higher crude protein was due to a bloom of annual plants after good rains in January. During year 2 Grassveld had significantly lower crude protein concentrations for all the months except for June and September were Grassveld and Ranteveld had similar concentrations. Els (2000) found the average crude protein concentrations of Grassveld in Namibia, dominated by *Stipagrostis* species, was 10.505% when the diet was selected by OF Dorper sheep. This was higher than both Year 1 and Year 2 for the Grassveld in this trial.

Grassveld had a similar average for both years of the trial. Ranteveld also had no difference between the two years of the trial. Grassveld had a lower average crude protein concentration compared to Ranteveld within the same year for both years of the trial period.

Figure 12 shows the mean monthly crude protein concentrations for the two veld types over two years. Ranteveld had a higher ($P<0.05$) average crude protein for all of the months except for July, August, December, January and February were there was no difference ($P>0.05$) between the veld types. Seasonal trends can also be observed with crude protein concentration being lower ($P<0.05$) for the winter months, April to December, for Grassveld, compared to January, February and March. Ranteveld showed a smaller drop in crude protein concentrations during the dry months, April to December, except for November. March, January and February had higher ($P<0.05$) crude protein concentrations compared to the other months for Ranteveld.

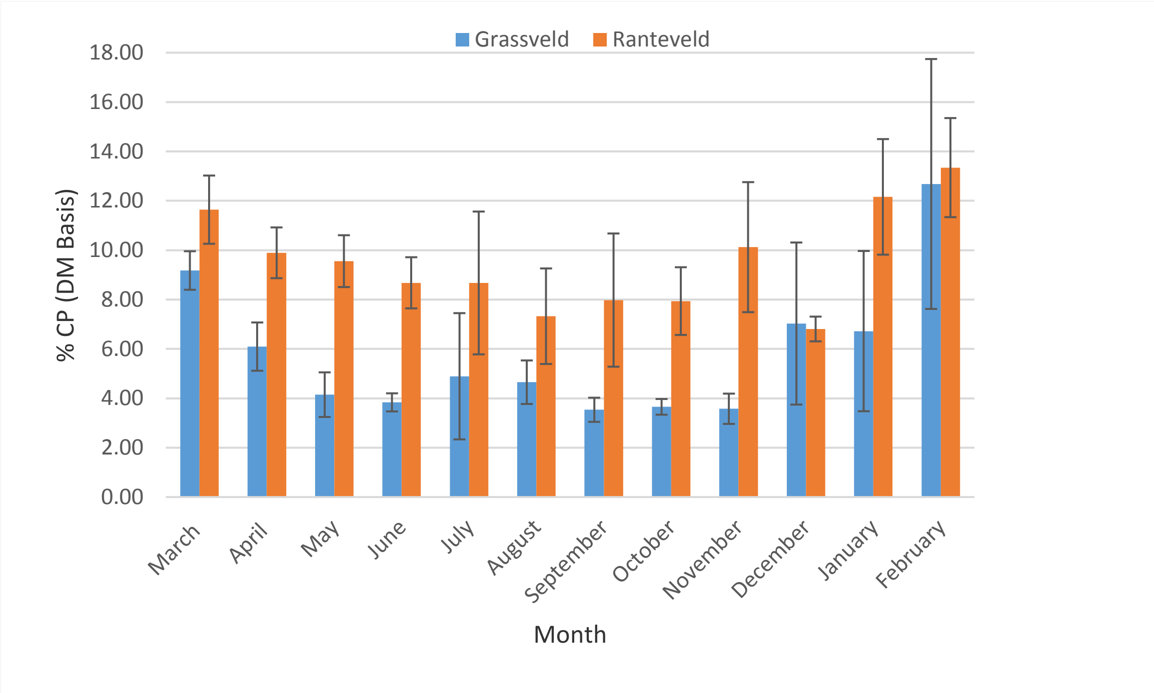

Figure 12 The monthly average crude protein percentage on a dry matter basis over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

In Figure 13 it can be clearly seen that the crude protein concentration provided by the different veld types varied greatly throughout the year. For the largest portion of the year the crude protein supplied by the veld types were lower than the requirements of a 60kg lactating ewe.

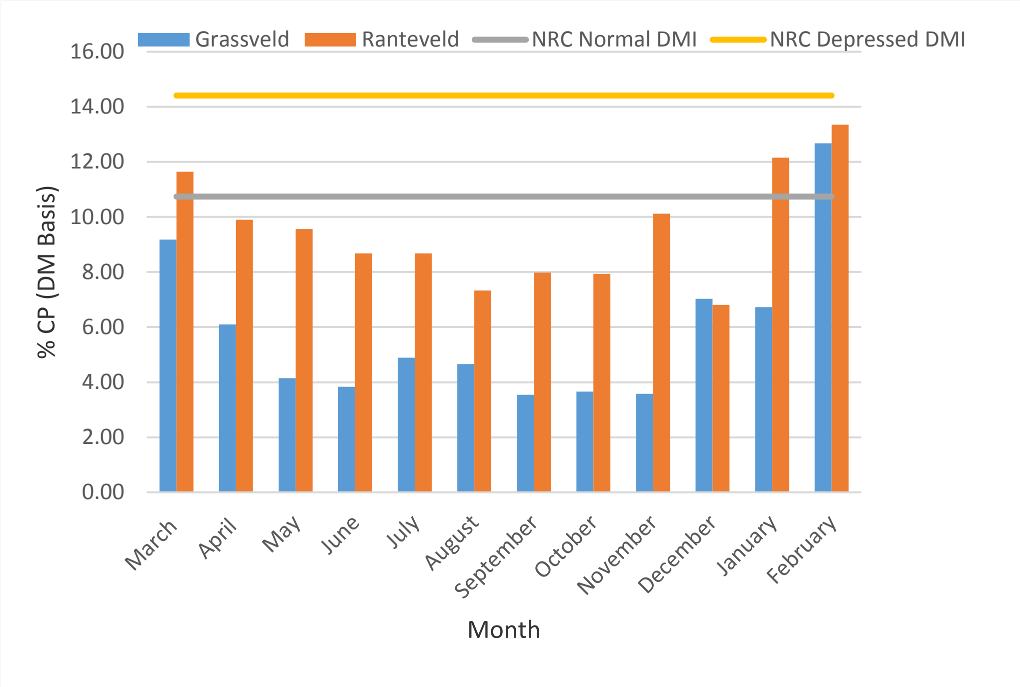

Figure 13 Average monthly crude protein % on a dry matter basis for Grassveld and Ranteveld over the two year trial period compared to the NRC protein concentration requirement for a 60 kg mature ewe in mid lactation with milk production of 0,58kg/day at dry matter intake levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day (NRC, 2007)

The biggest area of concern is the period from April to December. Even with normal levels of predicted DMI the crude protein concentration on both veld types dropped below the required level for 0.58kg of milk production from the 60kg ewe at 20% undegradable intake protein (UIP). Another concern during this period is the DMI levels. It is expected that the DMI levels will be lower during the winter months due to lower digestibility, palatability and availability (Cordova *et al.* 1978, De Waal 1990, Hardy *et al.* 1997). Moore *et al.,* (1999) showed a decrease in organic dry matter intake when forage crude protein drops below 88g/kg. The lower DMI levels require higher concentrations of CP to sustain the predicted milk production of 0.58kg/day. Faure *et al.,* (1982) found similar results when they quantified grazing for Karakul sheep in the Gordonia district of the Northern Cape. These authors found an average crude protein of 8.00% and 11.20% on Kalahari sand veld and Orange River Broken veld respectively. According to the NRC (1975) as used in the trial by Faure *et al.,* (1982) these protein levels were sufficient to support a non-reproducing penned sheep of 50kg.

4.3.2. Phosphorus (P)

The phosphorus results obtained from the oesophageally fistulated sheep are presented in Table 6. There was significant variation between camps as well as between months within a camp.

Table 6 The phosphorus percentage on a dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae.

	Grassveld		Ranteveld	
	Year 1 (±SD)	Year 2 (±SD)	Year 1 (±SD)	Year 2 (±SD)
March	0.24[a] (0.024)	0.28[ab] (0.021)	0.28[ab] (0.035)	0.30[b] (0.012)
April	0.23[a] (0.017)	0.20[a] (0.020)	0.24[a] (0.015)	0.32[b] (0.069)
May	0.24[b] (0.025)	0.18[a] (0.019)	0.21[ab] (0.019)	0.19[ab] (0.012)
June	0.24[b] (0.009)	0.17[a] (0.015)	0.16[a] (0.014)	0.17[a] (0.007)
July	0.23[a] (0.016)	0.21[a] (0.044)	0.19[a] (0.068)	0.22[a] (0.002)
August	0.25[b] (0.041)	0.20[ab] (0.009)	0.18[a] (0.013)	0.16[a] (0.018)
September	0.14[a] (0.015)	0.21[b] (0.045)	0.18[a] (0.009)	0.21[b] (0.026)
October	0.15[a] (0.036)	0.17[a] (0.015)	0.17[a] (0.013)	0.20[a] (0.015)
November	0.15[a] (0.021)	0.17[a] (0.007)	0.16[a] (0.017)	0.28[b] (0.023)
December	0.17[a] (0.020)	0.21[b] (0.012)	0.15[a] (0.010)	0.18[a] (0.015)
January	0.19[a] (0.030)	0.21[a] (0.016)	0.28[b] (0.064)	0.29[b] (0.013)
February	0.47[c] (0.034)	0.21[a] (0.011)	0.29[b] (0.013)	0.29[b] (0.031)
Average	0.22[b] (0.087)	0.20[a] (0.036)	0.21[a] (0.057)	0.23[b] (0.059)

[abcd] Row means with different superscripts differ significantly ($P<0.05$)

The highest P concentration was found in February of year 1 in Grassveld. During this month the P concentration rose to 0.47%. This high level of P was obtained due to a flush of green growth after high rainfall levels in the preceding month as can be seen in Figure 7. This high level was not sustained for a long period and dropped down to 0.28% in the following month. The lowest P concentrations was found in Grassveld during the dry season of year 1. In September the P concentration dropped to its lowest concentration of 0.14%. The phosphorus concentration showed little variation between months for the two years in both camps. The Grassveld camp had higher phosphorus concentrations for May, June, and February during year 1. Grassveld had a higher phosphorus concentration for September of year 2 compared to year 1. For Ranteveld there was differences for the months of April and November between the two years. In both cases year 2 had the higher phosphorus concentration. During year 1 there were great variation in phosphorus concentrations. Grassveld had higher P concentrations than Ranteveld for June, July, August and February of year 1, the P concentration in Ranteveld was significantly higher for April and November. Year 2 had more consistent differences between Grassveld and Ranteveld with Ranteveld having higher phosphorus concentrations for April, November, January and February. Els (2000) found the average phosphorus concentrations of Grassveld in Namibia, dominated by *Stipagrostis* species, was 0.195 % when the diet was selected by OF Dorper sheep. This was lower than both Year 1 and Year 2 for the Grassveld in this trial.

Low growth activity by vegetation leads to low P levels. Similar results were reported by Du Toit *et al.* (1988) and Roodt (2012). The reported results are lower in P concentration than the requirements set by the NRC (2007) for most production stages of sheep. Masters (1996) noted that prolonged grazing of dry pastures by sheep may lead to phosphorus deficiency leading to reduced growth and reduced reproductive rates. It should be noted that caution should be taken in considering these results as it was shown by Wallace *et al.* (1972) and Holenchek *et al.* (1982) that the oesophageal fistula technique may lead to an overestimation of P levels due to the P present in the saliva of animals. The fact that endogenous P from saliva may have been present in the extrusa samples points to significant P shortages during the winter months.

Figure 14 shows the monthly average phosphorus concentration for Grassveld and Ranteveld for the trial period. Seasonal trends can be observed with the P concentration dropping ($P<0.05$) during the dry months, April – January, compared to March and February for Grassveld. In the Ranteveld decreased ($P<0.05$) in P concentration were observed from May - December when compared to the wet months of January, February, March and April. A high standard deviation was observed for February in the Grassveld, this was due to the high P concentrations recorded during February of year 1. There was no difference ($P>0.05$) between Grassveld and Ranteveld in terms of the average phosphorus concentration for 10 months of the year. Grassveld showed a higher ($P<0.05$) average phosphorus concentration for August. Ranteveld had a higher ($P<0.05$) average crude protein for January.

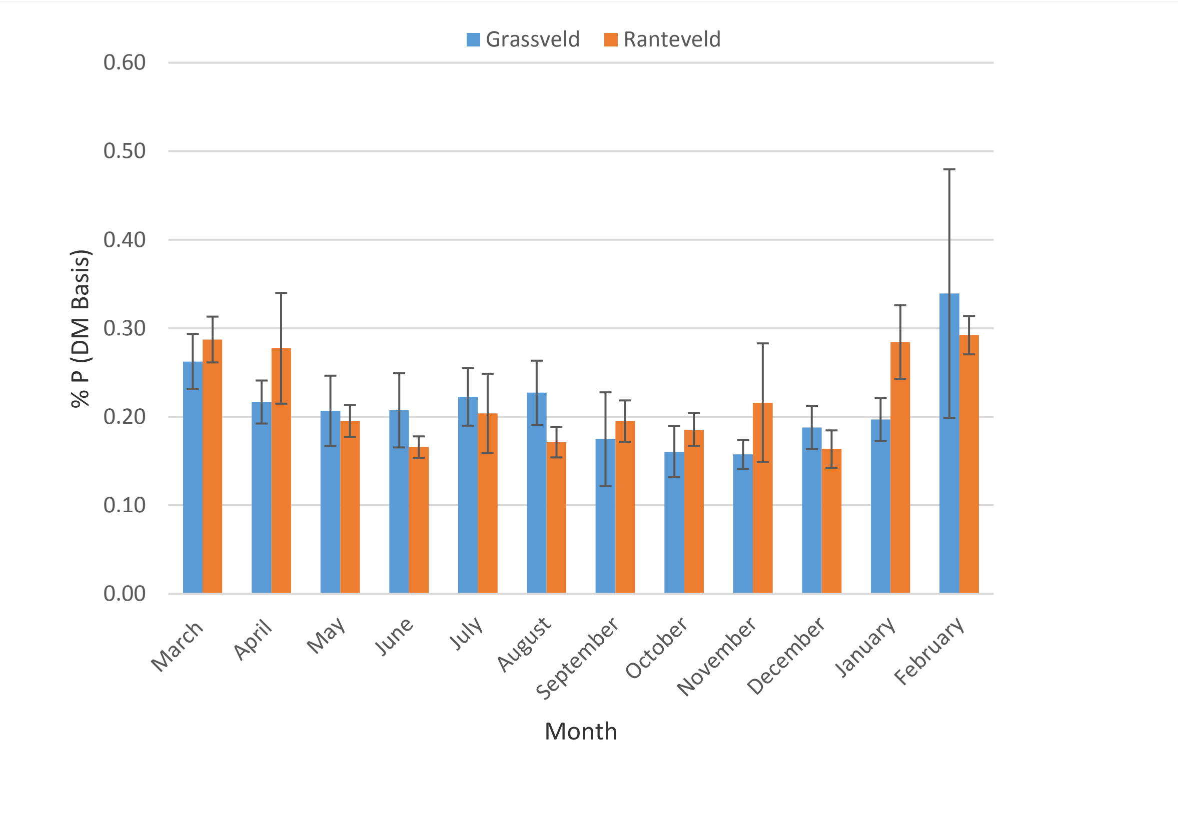

Figure 14 The monthly average phosphorus percentage over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

In Figure 15 the average monthly phosphorus concentration is shown and compared to the NRC (2007) requirements for a lactating ewe at two levels of dry matter intake. From Figure 15 it can be seen that the concentrations of phosphorus in both veld types are well below the required concentrations given by the NRC (2007) for the largest part of the year.

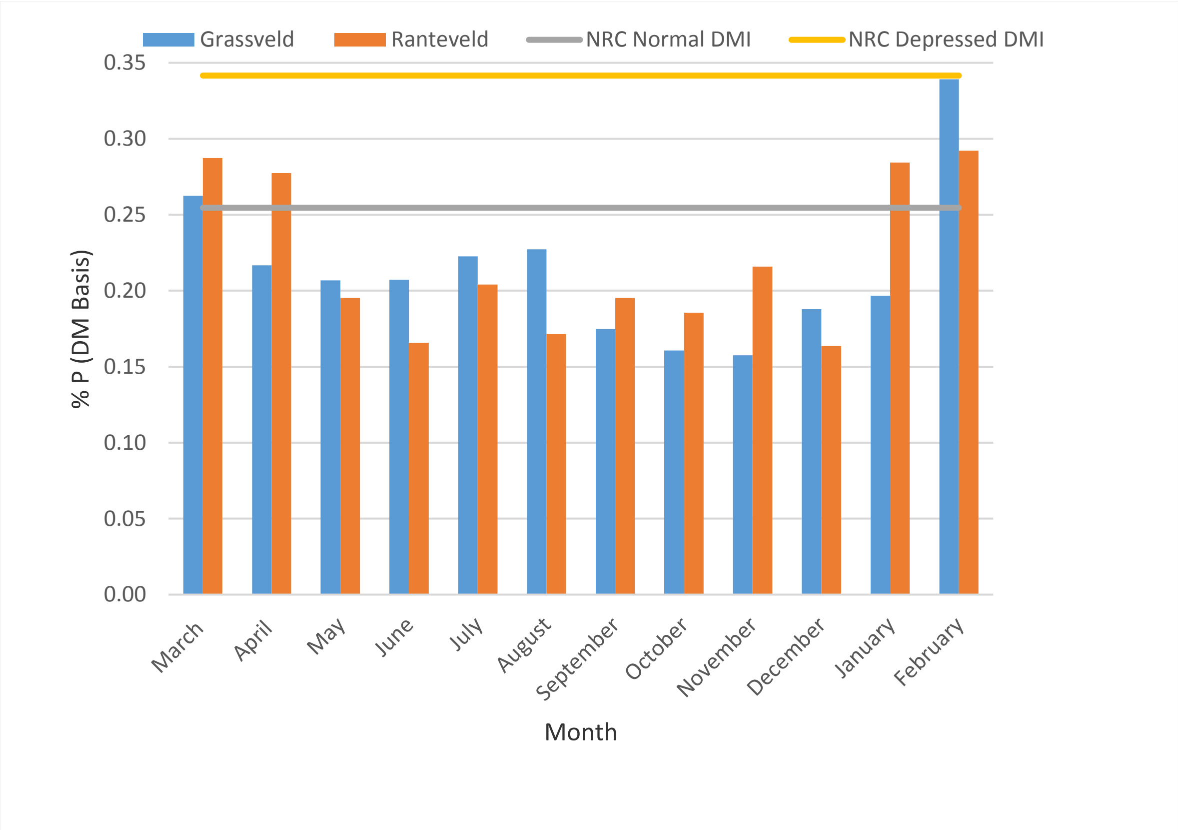

Figure 15 Average monthly phosphorus % on a dry matter basis for Grassveld and Ranteveld over the two year trial period compared to the NRC phosphorus concentration requirement for a 60 kg mature ewe in mid lactation with milk production of 0,58kg/day at dry matter intake levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day (NRC, 2007)

Phosphorus supplementation is highly advised on the areas sampled for this trial. Various studies have been concluded under South African conditions showing moderate to acute P deficiencies in soils around the country. Trials indicating positive production reactions when grazing cattle was given a phosphorus supplement was done by Read *et al.* (1986), De Waal (1990), and Roodt (2012). Although production responses on sheep supplemented with phosphorus was not observed by De Waal *et al.* (1980; 1981) it was postulated that phosphorus might not have been the limiting nutrient and that the lack of crude protein and energy was the reason for the lack of response to phosphorus supplementation. Read *et al.* (1986a) found no differences in conception rates, lambing percentage, weaning percentage and lamb birth mass between supplemented and non-supplemented animals, but found higher weaning weights on the lambs of ewes that was supplemented with phosphorus. This may have been due to the higher milk production of ewes supplemented with phosphorus, resulting from higher intakes stimulated by phosphorus supplementation. Little *et al.* (1978) and Read *et al.* (1986a) found that phosphorus supplemented ewes had less resorption of phosphorus from their bones during early lactation compared to those who did not receive a phosphorus supplement. Read *et al.* (1986a) further postulated that due to the fact that phosphorus deficiencies was not acutely diagnosed in sheep, it did not mean that sheep were not susceptible to phosphorus deficiencies. Read *et al.* (1986a) showed by means of bone phosphorus levels that sheep were susceptible to phosphorus deficiencies.

4.3.3. Calcium (Ca)

The calcium results obtained from the oesophageally fistulated sheep are presented in Table 7. There were differences (P<0.05) between camps for most of the months. Ranteveld had higher (P<0.05) Ca concentrations compared to Grassveld for March, June, September, October, November and December of year 1. Ranteveld also had higher (P<0.05) calcium concentrations compared to Grassveld for year 2 in April, May, June, July, August, October, November and February. The only month were Grassveld had a higher (P<0.05) calcium concentration than Ranteveld was for February of year 1. This level was high due to active plant growth after good rains.

Table 7 The calcium percentage on a dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae.

	Grassveld		Ranteveld	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2 (±SD)**
March	0.55[a] (0.204)	0.78[ab] (0.106)	1.02[b] (0.155)	0.84[b] (0.029)
April	0.47[ab] (0.068)	0.38[a] (0.049)	0.83[bc] (0.227)	1.09[c] (0.125)
May	0.48[a] (0.072)	0.36[a] (0.049)	0.62[a] (0.314)	1.54[b] (0.093)
June	0.41[a] (0.048)	0.42[a] (0.062)	1.23[b] (0.267)	1.51[b] (0.064)
July	0.59[ab] (0.314)	0.45[a] (0.059)	0.85[bc] (0.168)	1.19[c] (0.103)
August	0.63[a] (0.117)	0.59[a] (0.071)	0.73[a] (0.406)	1.30[b] (0.308)
September	0.25[a] (0.049)	0.37[ab] (0.129)	1.30[c] (0.487)	0.68[b] (0.178)
October	0.26[a] (0.085)	0.28[a] (0.015)	1.19[b] (0.154)	0.83[b] (0.250)
November	0.27[a] (0.058)	0.29[a] (0.018)	0.94[b] (0.298)	1.05[b] (0.025)
December	0.29[a] (0.050)	0.67[b] (0.023)	0.75[b] (0.141)	0.85[b] (0.218)
January	0.30[a] (0.024)	0.72[bc] (0.046)	0.57[ab] (0.099)	1.06[c] (0.085)
February	1.65[c] (0.285)	0.70[a] (0.045)	0.85[ab] (0.113)	1.21[b] (0.108)
Average	0.51[a] (0.393)	0.50[a] (0.182)	0.91[b] (0.318)	1.10[c] (0.293)

[abcd] Row means with different superscripts differ significantly (P<0.05)

The lowest calcium concentrations was found in Grassveld during the late winter months before the first rains. September and October of year one Grassveld had calcium concentrations of only 0.25% and 0.26% respectively.

In Grassveld the calcium concentration was relatively constant between years within a month. There were differences ($P<0.05$) between years only for December, January and February, with year 2 having higher ($P<0.05$) calcium concentration levels for January and December. In Ranteveld there was a difference ($P<0.05$) within months between years for May, August, September and January, with September being the only month were year 1 had a higher ($P<0.05$) calcium concentration than year 2.

There was no difference between the annual averages for Grassveld between the two years. The average calcium concentration for Ranteveld differed ($P<0.05$) between the two years with year 2 being higher than year 1. Ranteveld had higher calcium concentrations for both year 1 and year 2 compared to Grassveld.

Calcium concentration followed a seasonal trend as shown in Figure 16. During the dry months of April to November the calcium concentration in the Grassveld was lower ($P<0.05$) compared to February except for July and August which were similar. In Ranteveld there was less of a seasonal effect with similar ($P>0.05$) calcium concentrations between all the months except for June which had a higher ($P<0.05$) calcium concertation compared to March, December and January. There was no direct correlation to season or rainfall as shown in Figure 7. Ranteveld had higher ($P<0.05$) calcium concentrations compared to Grassveld for April, May, June, July, September, October and November.

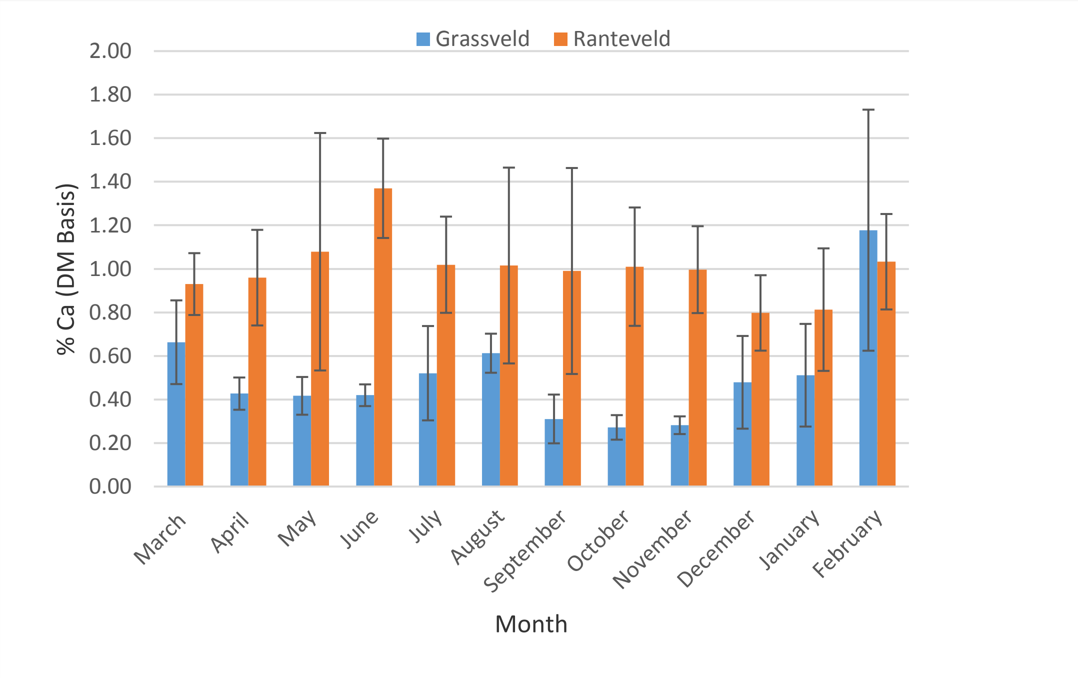

Figure 16 The monthly average calcium percentage on a dry matter basis over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae.

Figure 17 shows that the calcium concentrations in both veld types were high enough to sustain a 60 kg mature ewe in mid lactation with a daily milk production of 0.58kg/day during most months. Only during September and October of the first year did the level drop to below 0.27% as suggested as a minimum by the NRC (2007).

High calcium levels in the drinking water further increased the total daily intake of calcium by sheep. High calcium concentrations leads to lower absorption of magnesium, which can be reflected in lower growth and production rates (McDowell, 2003).

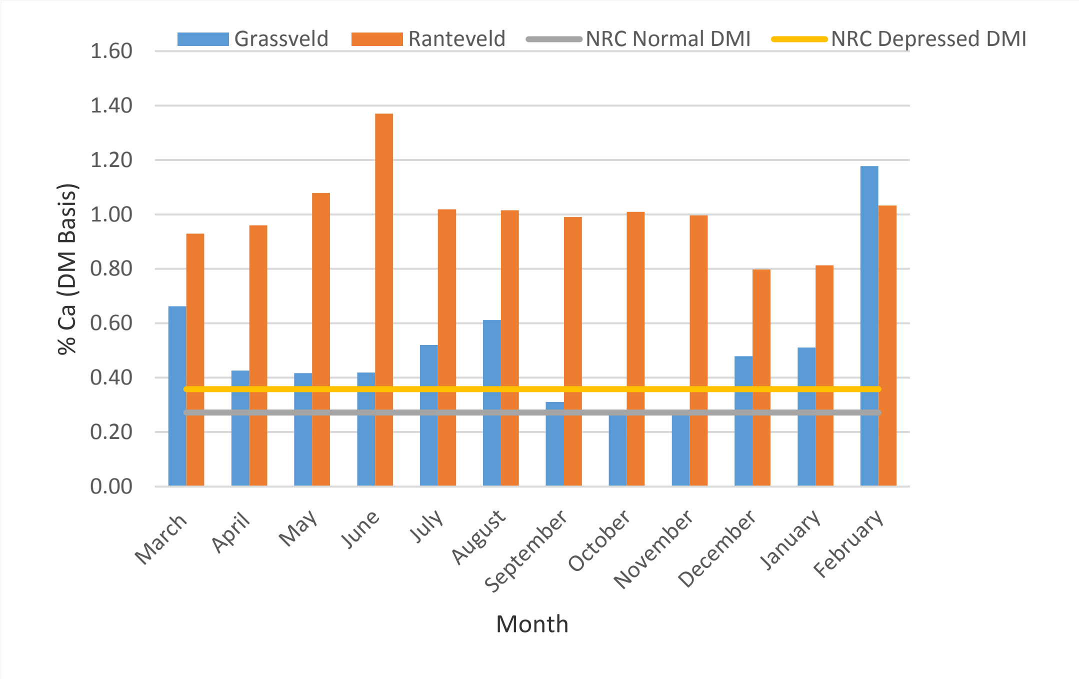

Figure 17 Average monthly calcium % on a dry matter basis for Grassveld and Ranteveld over the two year trial period compared to the NRC calcium concentration requirement for a 60 kg mature ewe in mid lactation with milk production of 0,58kg/day at dry matter intake levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day (NRC, 2007)

4.3.4. Calcium to Phosphorus ratio (Ca:P)

The calcium : phosphorus (Ca:P) ratio in Grassveld did not vary much with the lowest being 1.97 and he highest 3.47. For Ranteveld on the other hand there is great variation with the lowest being 3.24 and the highest 8.26. The calcium to phosphorus ratio is of great concern as the absorption of either of the two elements may be affected when the ratio drops below 1:1 or goes above 7:1 (NRC 1975). Acording to the NRC (2007) optimal absorption and performance can be obtained in ruminants with Ca : P ratios of 1 : 1 to 2.5 : 1. Wan Zahari *et al.*, (1990) pointed out that when phosphorus was deficient, a Ca:P ratio of 3.6 was detrimental to sheep. This is of great importance in this case where the highest Ca:P ratio was found in June in the

Ranteveld over the same period were phosphorus concentrations were deficient according to the NRC (2007). The Ca:P ratios for the trial period is shown in Figure 18.

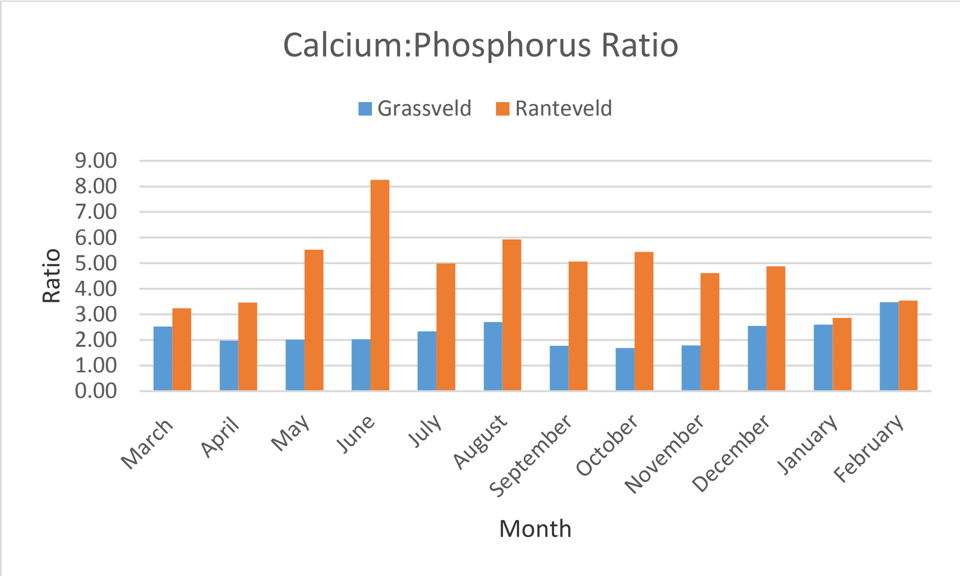

Figure 18 The average calcium to phosphorus ratio for two veld types in the Northern Cape over a two year period as quantified by grazing sheep fitted with oesophageal fistulae.

4.3.5. Magnesium (Mg)

The magnesium concentrations that were obtained during the trial are given in Table 8. The lowest concentration of magnesium was 0.08% in Grassveld and the highest 0.79% in Ranteveld.

The only difference between the two years within a month for Grassveld was during July where the magnesium concentration was higher for year 1 compared to year 2. In the Ranteveld there were differences between year 1 and year 2 for July, September, October and November with the magnesium concentrations being higher for year 1 for all of these months.

The Ranteveld had higher magnesium concentrations during year 1 for all of the months except for January and February where no difference was observed between the veld types. During year two there was no difference ($P>0.05$) between the veld types within months except for April, May and June, the concentrations were higher ($P<0.05$) for Ranteveld for all of these months.

Grassveld had similar averages for year and year 2. Ranteveld had a higher average magnesium concentration for year 1 compared to year 2. Ranteveld had higher average magnesium concentrations for both years compared to Grassveld.

Table 8 The magnesium percentage on dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

	Grassveld		**Ranteveld**	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2 (±SD)**
March	0.12^{a} (0.033)	0.15^{ab} (0.018)	0.42^{c} (0.055)	0.30^{bc} (0.044)
April	0.15^{ab} (0.014)	0.10^{a} (0.011)	0.40^{c} (0.062)	0.35^{bc} (0.114)
May	0.11^{a} (0.032)	0.08^{a} (0.009)	0.65^{b} (0.147)	0.43^{b} (0.045)
June	0.08^{a} (0.013)	0.10^{a} (0.005)	0.59^{b} (0.101)	0.50^{b} (0.018)
July	0.39^{b} (0.497)	0.11^{a} (0.020)	0.79^{c} (0.014)	0.32^{ab} (0.034)
August	0.14^{ab} (0.012)	0.11^{a} (0.015)	0.41^{c} (0.265)	0.31^{bc} (0.037)
September	0.08^{a} (0.016)	0.09^{a} (0.007)	0.74^{b} (0.264)	0.19^{a} (0.028)
October	0.16^{a} (0.100)	0.08^{a} (0.003)	0.72^{b} (0.087)	0.26^{a} (0.093)
November	0.10^{a} (0.010)	0.09^{a} (0.001)	0.58^{b} (0.218)	0.26^{a} (0.012)
December	0.08^{a} (0.008)	0.13^{a} (0.005)	0.39^{b} (0.103)	0.26^{ab} (0.055)
January	0.08^{a} (0.009)	0.17^{a} (0.029)	0.19^{a} (0.045)	0.25^{a} (0.017)
February	0.28^{a} (0.051)	0.15^{a} (0.009)	0.34^{a} (0.067)	0.30^{a} (0.019)
Average	0.15^{a} (0.154)	0.11^{a}(0.032)	0.52^{c} (0.216)	0.31^{b} (0.094)

^{abcd} Row means with different superscripts differ significantly (P<0.05)

Magnesium concentrations did not have a seasonal pattern although concentrations tended to be higher during the dry months in Ranteveld. Figure 19 shows the large variation of magnesium concentration between Ranteveld and Grassveld. There were differences (P<0.05) for all of the months between Grassveld and Ranteveld except for July, January and February.

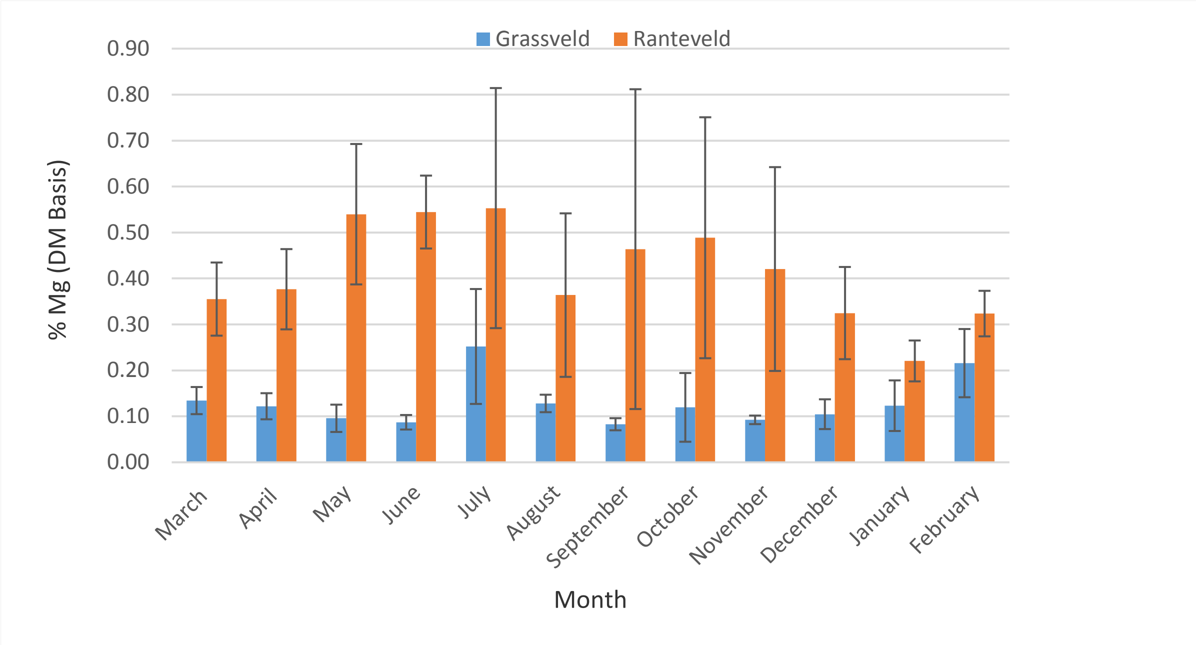

Figure 19 The monthly average magnesium percentage on a dry matter basis over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

Figure 20 shows that the magnesium concentration on Ranteveld is sufficient for a 60kg ewe during lactation for all of the months on normal and low levels of dry matter intake (NRC, 2007). The Grassveld will not be able to supply sufficient magnesium to a lactating ewe of 60kg producing 0.58kg of milk per day except for March, April, August, October, January and February (NRC, 2007). Even at normal levels of dry matter intake (2.68% BW) the magnesium concentration is too low during June, September and November to supply the magnesium required by the ewe (NRC, 2007).

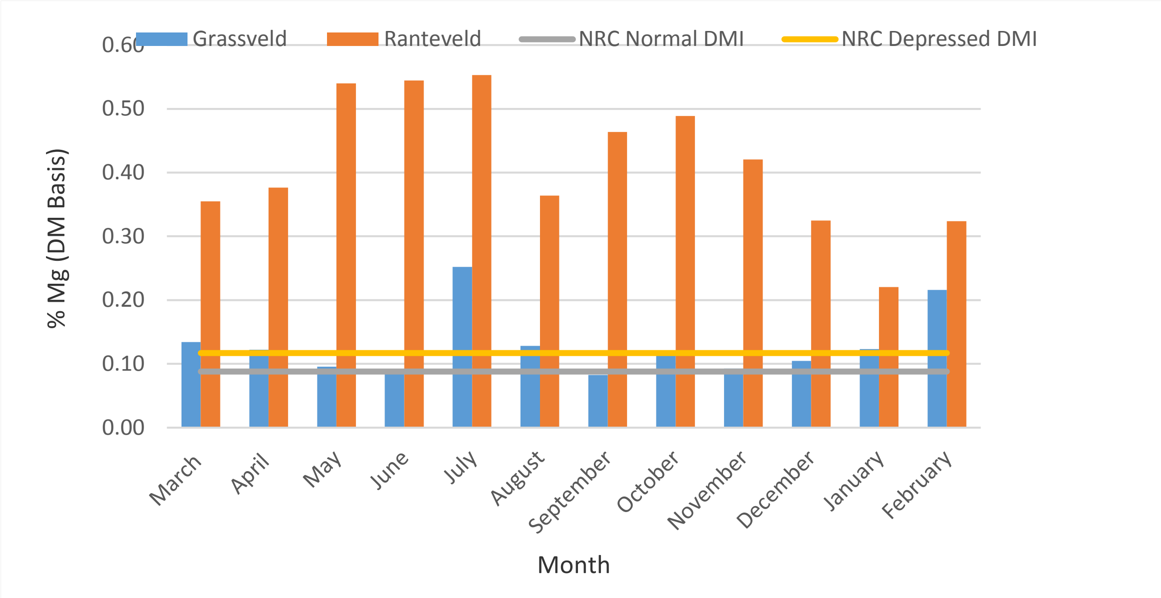

Figure 20 Average monthly magnesium % on a dry matter basis for Grassveld and Ranteveld over the two year trial period compared to the NRC magnesium concentration requirement for a 60 kg mature ewe in mid lactation with milk production of 0,58kg/day at dry matter intake levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day (NRC, 2007)

4.3.6. Copper (Cu)

Copper concentrations for the trial is given in Table 9. The lowest copper concentrations were during November year 1 in Grassveld at a level of 1.90 mg/kg. The highest concentration was found in January of year 2 in Ranteveld at a level of 11.79 mg/kg.

Table 9 The copper concentration (mg/kg) on a dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

	Grassveld		Ranteveld	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2 (±SD)**
March	4.88[ab] (0.324)	4.08[a] (0.141)	7.87[c] (0.461)	6.09[b] (0.774)
April	3.80[a] (0.903)	3.07[a] (0.293)	6.11[b] (0.651)	6.99[b] (1.396)
May	2.77[a] (0.436)	2.86[a] (0.618)	5.16[b] (0.499)	5.91[b] (0.526)
June	2.21[a] (0.128)	4.49[b] (0.308)	5.32[c] (0.860)	5.90[bc] (0.525)
July	4.35[a] (2.291)	4.55[ab] (0.288)	6.16[bc] (1.425)	7.05[c] (0.537)
August	6.28[ab] (1.153)	5.18[ab] (0.319)	4.87[a] (2.172)	6.86[b] (0.563)
September	2.16[a] (0.387)	4.67[b] (0.305)	5.05[bc] (0.119)	6.46[c] (0.918)
October	1.98[a] (0.133)	5.02[b] (0.617)	5.81[bc] (0.268)	7.42[c] (0.793)
November	1.90[a] (0.127)	6.07[b] (0.800)	4.80[b] (0.534)	10.01[c] (0.289)
December	2.43[a] (0.231)	7.78[c] (0.328)	4.69[b] (0.179)	7.65[c] (0.315)
January	2.62[a] (0.249)	7.62[c] (0.190)	5.44[b] (1.096)	11.79[d] (1.442)
February	6.56[ab] (0.829)	8.02[b] (0.549)	5.84[a] (0.903)	11.37[c] (0.401)
Average	3.49[a] (1.765)	5.28[b] (1.738)	5.59[b] (1.158)	7.79[c] (2.127)

[abcd] Row means with different superscripts differ significantly ($P<0.05$)

There was no seasonal trend within Grassveld between the two years. Differences in copper concentrations was found within Grassveld for June, September, October, November, December and January between year 1 and year 2. The concentrations of these months were all higher for year 2 compared to year 1. In the and year Ranteveld there were differences between March, August, November, December, January and February for year 1 and year 2. The copper concentration for March year 1 was higher than for March year 2, conversely all the other months that differ in the Ranteveld had higher levels for year 2.

Ranteveld had higher copper concentrations than Grassveld during year 1 for all of the months except for August and February, where no difference was found. Year 2 also showed higher copper concentrations for Ranteveld with only June, August and December showing no difference between Grassveld and Ranteveld.

Grassveld had different annual averages with year 2 being higher than year 1. Ranteveld also had higher average copper concentrations for year 2 compared to year 1. Ranteveld had higher average copper concentrations than Grassveld for year 1 and year 2 respectively.

Copper concentration showed no seasonal trend. In Figure 21 it can be seen that there is no strong trend of copper concentration to season. Copper concentration was higher ($P<0.05$) in the Ranteveld for the first part of the year, with no difference ($P>0.05$) in copper concentrations being found between Grassveld and Ranteveld for July, August, September, November, December, January and February.

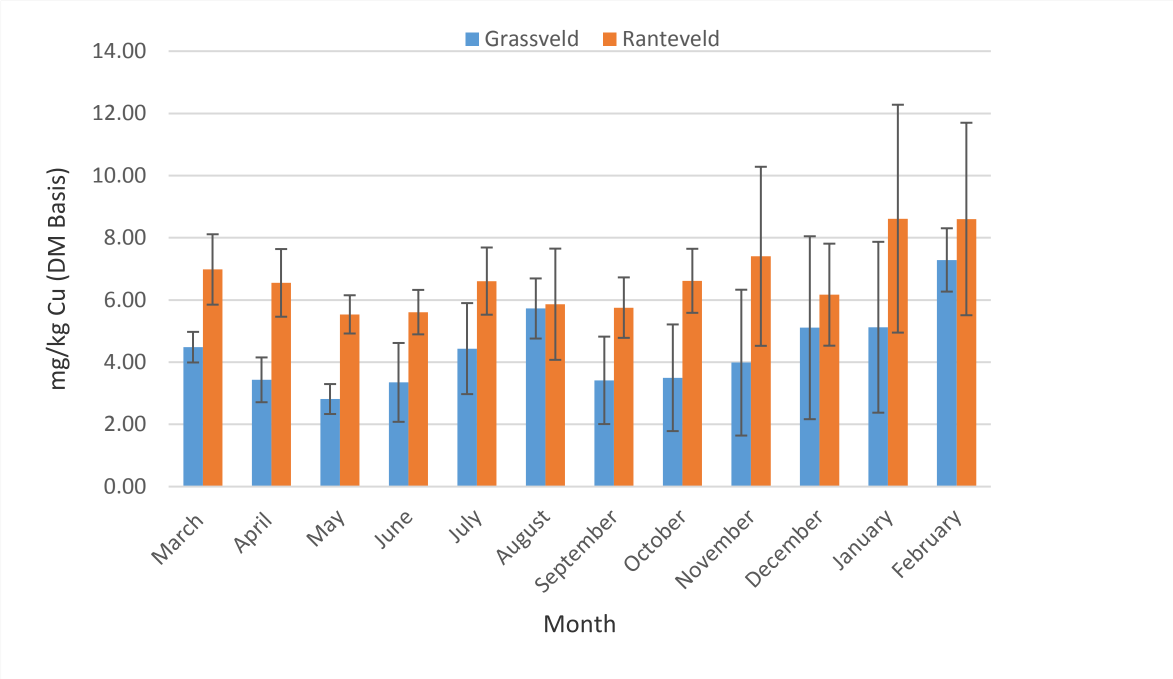

Figure 21 The monthly average copper concentration on a dry matter basis over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

The copper concentration of Grassveld is lower than the recommended concentration for a lactating ewe of 60kg, producing 0.58kg of milk for all of the months except for August and February (NRC, 2007). Figure 22 shows the concentrations of copper needed by a lactating ewe compared to that which the two veld types provide.

Relatively high concentrations of copper was found in the Ranteveld during March, November, January and February. Although these levels are below the maximal tolerable levels of 15mg/kg as reported by the NRC (2007), high levels of DM intake and low levels of molybdenum in the diet could raise the risk of copper toxicity of animals grazing the Ranteveld at these times of the year.

According to the NRC, (2005) the maximum tolerable level for copper in the diet of sheep is 15mg/kg on a DM basis when normal levels of molybdenum and sulphur are present. The high levels of iron in the diet (Figure 24) may lead to lower absorption of copper (Spears, 2003). The practice of copper supplementation must be approached with great care due to the risk of copper toxicity that is prevalent in sheep. Various breed and mineral effects can influence the success and the risk involved with copper supplementation as pointed out by Van Ryssen (1979) and Harrison *et al.* (1987).

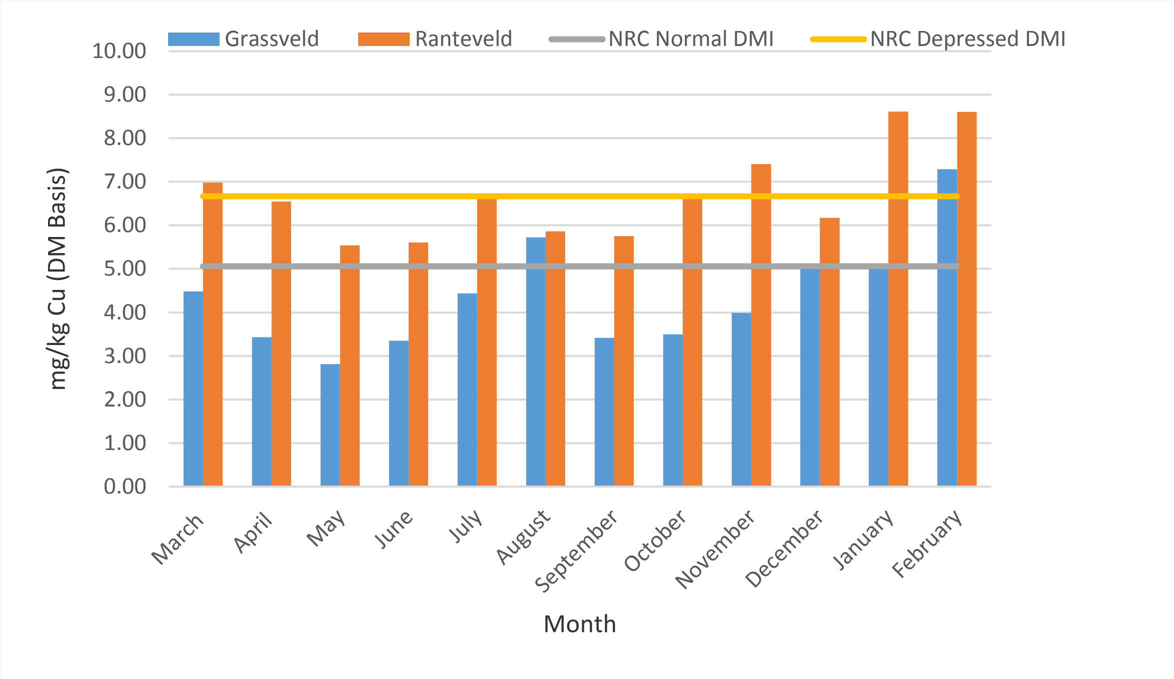

Figure 22 Average monthly copper concentration (mg/kg) on a dry matter basis for Grassveld and Ranteveld over the two year trial period compared to the NRC copper concentration requirement for a 60 kg mature ewe in mid lactation with milk production of 0,58kg/day at dry matter intake levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day (NRC, 2007)

4.3.7. Iron (Fe)

The iron concentrations for the trial is shown in Table 10. The average iron concentrations differed (P<0.05) between the two camps. The lowest iron concentration was found in Grassveld during March of year 1 with a concentration of 356.06 mg/kg. The highest concentration was found in Ranteveld during March of year 1, the concentration here being 2004.18 mg/kg. The month with the biggest difference between camps within a year is March of year 1.

Table 10 The iron concentration (mg/kg) on a dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

	Grassveld		Ranteveld	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2 (±SD)**
March	356.1^{a} (77.22)	792.77^{ab} (94.46)	2004.2^{c} (222.36)	960.6^{b} (156.78)
April	390.6^{a} (86.01)	966.9^{b} (129.73)	1778.2^{c} (470.49)	1245.1^{b} (260.86)
May	554.2^{a} (11.28)	943.6^{ab} (53.85)	1162.9^{b} (202.02)	780.9^{ab} (179.96)
June	468.6^{a} (123.76)	861.3^{ab} (162.12)	1307.0^{b} (359.77)	1101.5^{b} (43.16)
July	721.8^{a} (302.43)	831.4^{a} (109.65)	1356.3^{c} (772.84)	1138.4^{ab} (178.12)
August	578.9^{a} (54.14)	774.9^{a} (95.33)	773.9^{a} (125.78)	1234.2^{b} (58.51)
September	478.3^{a} (55.90)	856.0^{a} (158.40)	818.4^{a} (225.19)	1389.3^{b} (314.76)
October	509.0^{a} (83.06)	690.5^{a} (54.87)	832.6^{a} (114.24)	1435.2^{b} (147.48)
November	536.5^{a} (28.96)	812.7^{ab} (71.40)	985.3^{bc} (34.42)	1314.8^{c} (58.23)
December	643.9^{ab} (120.12)	380.1^{a} (37.50)	832.2^{bc} (64.00)	1163.8^{c} (60.78)
January	647.5^{ab} (112.35)	471.4^{a} (77.54)	939.9^{bc} (252.70)	1120.8^{c} (78.88)
February	763.5^{a} (196.78)	504.3^{a} (73.92)	696.9^{a} (134.77)	1360.5^{b} (190.50)
Average	554.1^{a} (141.41)	740.5^{b} (202.79)	1123.9^{c} (482.54)	1188.6^{c} (229.81)

^{abcd} Row means with different superscripts differ significantly (P>0.05)

Grassveld showed very little variation between years within months. All of the months had similar values between years except for April in year 2 which had a higher iron concentration of 966.92 mg/kg compared to year 1 at 360.60mg/kg. Ranteveld showed greater variation between the two years within months. Year 1 had higher iron concentrations for March and April compared to year 2. Year 2 in the Ranteveld showed higher values for August, September, October and February.

The similarities between Ranteveld and Grassveld was limited to the second half of year 1. Year 1 showed different iron concentrations between Ranteveld and Grassveld from March to July. From August to February concentrations were similar between camps in year 1. During year 2 there were no differences between Grassveld and Ranteveld for March, April, May, June and July. Significant differences were however shown for the months of August to February. Ranteveld had higher iron concentrations for all of the months that differed.

Grassveld had a higher average iron concentration during year 2 compared to year 1. Ranteveld had similar average iron concentrations for the two years. Ranteveld had higher average iron concentrations compared to Grassveld for year 1 and year 2.

Figure 23 shows that there is no clear seasonal trend for iron concentration. Differences (P<0.05) however can be seen between Grassveld and Ranteveld for March, April, June, October, November, December and January. Iron concentration is higher (P<0.05) in the Ranteveld for all of the months.

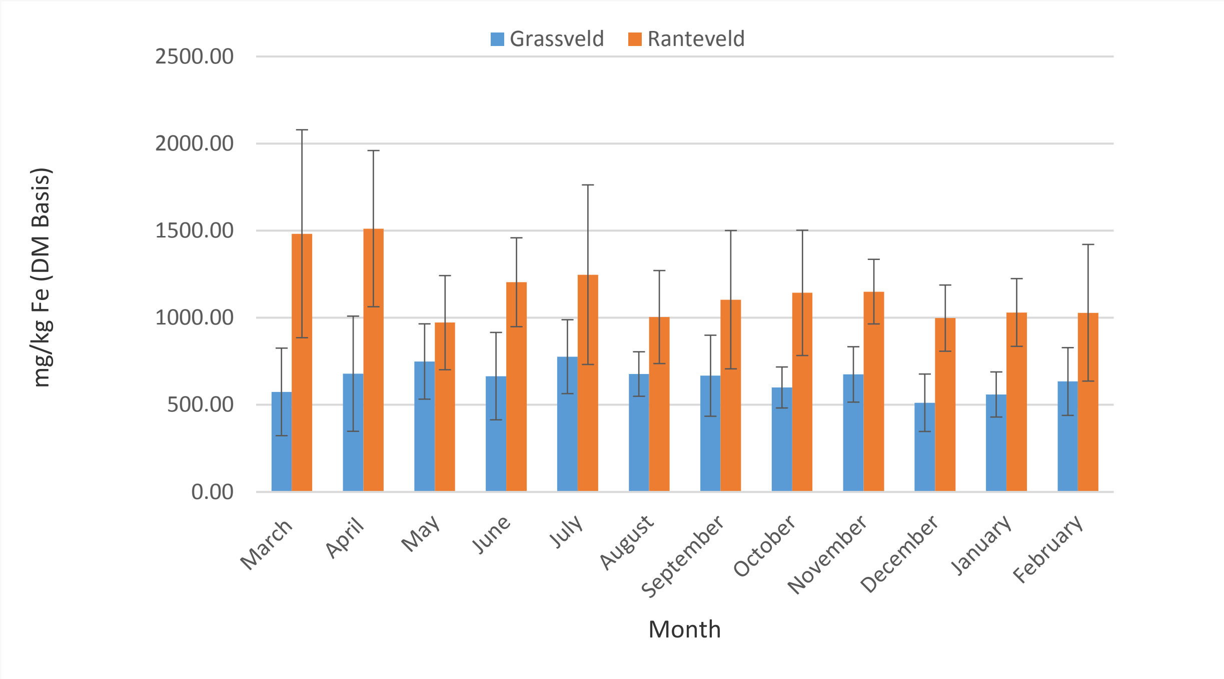

Figure 23 The monthly average iron concentration on a dry matter basis over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

From Figure 24 the high concentration of iron in the two veld types could clearly be observed. Iron concentrations in the diet at a normal DMI of 2.68% should be about 21mg/kg on a DM basis (NRC, 2007). The iron concentrations even at the lowest point during the year is more than 15 times higher than the recommended daily intake (NRC, 2007). At the highest iron concentration a 60kg ewe with a DMI of 2.68% would ingest more than 90 times the level of iron recommended by the NRC (2007). High dietary concentrations of iron reduces copper bio-availability (Spears, 2003).

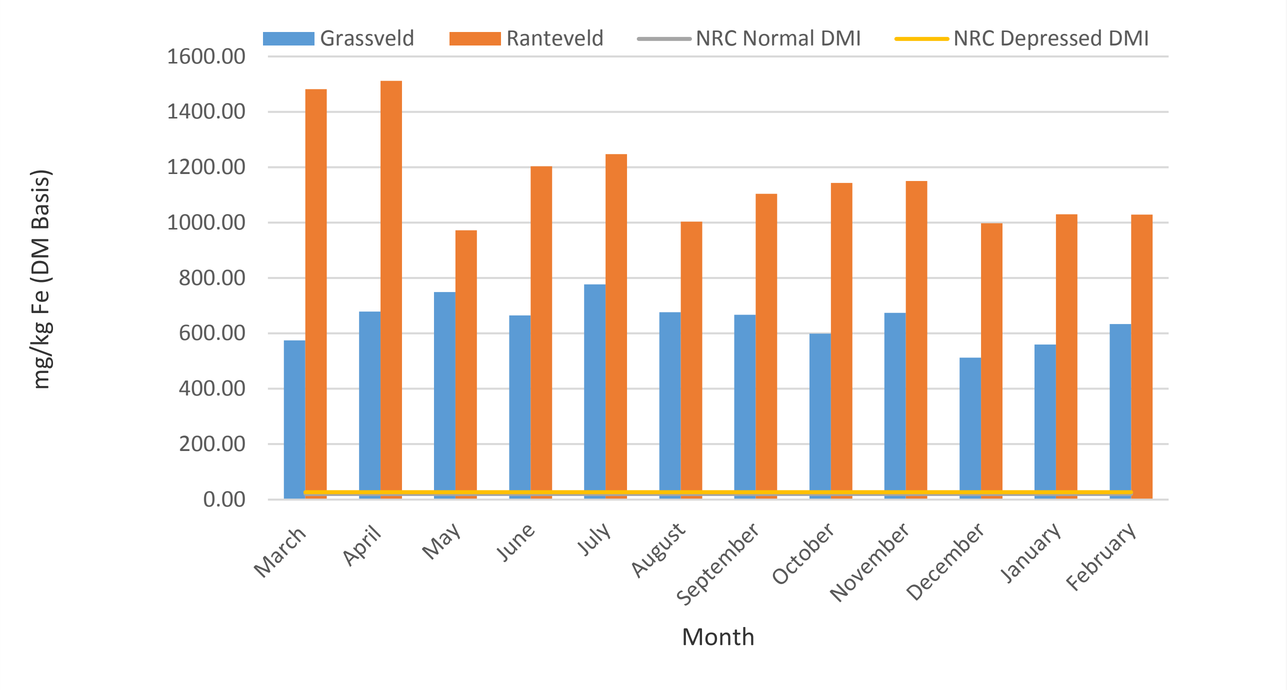

Figure 24 Average monthly iron concentration (mg/kg) on a dry matter basis for Grassveld and Ranteveld over the two year trial period compared to the NRC iron concentration requirement for a 60 kg mature ewe in mid lactation with milk production of 0,58kg/day at dry matter intake levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day (NRC, 2007)

The concentrations of iron that where found are very high. The NRC (2005) stated the highest tolerable concentration for iron as 500mg/kg DM. The levels of this trial especially in Ranteveld is much higher. Animals are able to adapt to these high iron concentrations by lowering the absorption of iron from the gastrointestinal tract as, shown by Fairweather-Tait and Wright (1984). These higher levels of iron can however affect the availability of other minerals in the diet, especially copper (Spears, 2003).

4.3.8. Manganese (Mn)

The results for manganese concentrations for this trial is shown in Table 11. The highest concentration observed during this trial was 109.36 mg/kg during August of year 2 in the Ranteveld. The lowest concentration was 14.76 mg/kg for September year 1 in the Grassveld.

Grassveld showed no difference between years within the same month. Ranteveld showed higher ($P<0.05$) manganese concentrations in year 1 for October and November. Year 2 had higher ($P<0.05$) levels during June and August for Ranteveld when compared to year 1.

During year 1 Ranteveld had higher manganese concentrations for all the months except for January and February when compared to Grassveld. The concentrations of January and February were similar for Ranteveld and Grassveld. Year 2 showed similar concentrations between Ranteveld and Grassveld for March, May, September, December and January. For all of the other months Ranteveld had higher values.

Table 11 The manganese concentration (mg/kg) on a dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

	Grassveld		Ranteveld	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2 (±SD)**
March	26.42[a] (3.339)	36.46[ab] (1.883)	65.81[c] (0.747)	54.75[bc] (10.704)
April	31.29[a] (4.353)	38.42[a] (4.331)	78.69[b] (11.165)	76.50[b] (32.774)
May	24.77[a] (6.084)	34.70[ab] (3.893)	80.47[b] (7.567)	58.98[b] (4.549)
June	20.22[a] (2.967)	29.99[a] (2.933)	80.86[b] (9.673)	108.78[c] (18.027)
July	21.35[a] (3.525)	27.93[a] (3.216)	102.33[b] (22.626)	85.91[b] (4.086)
August	26.25[a] (1.420)	30.03[a] (3.006)	62.67[b] (36.548)	109.36[c] (21.287)
September	14.76[a] (1.453)	30.07[ab] (2.706)	58.76[b] (22.945)	49.78[b] (3.433)
October	20.06[a] (9.142)	27.89[a] (1.466)	90.13[c] (15.415)	56.35[b] (5.785)
November	16.33[a] (0.957)	29.52[a] (0.300)	81.29[c] (23.449)	55.78[b] (3.805)
December	22.52[a] (5.478)	39.58[ab] (1.000)	72.88[b] (8.227)	54.12[b] (0.535)
January	22.66[a] (2.561)	42.11[ab] (3.044)	34.21[ab] (6.223)	56.30[b] (4.935)
February	48.31[a] (4.134)	46.83[ab] (2.118)	53.55[ab] (7.713)	83.45[c] (10.995)
Average	24.58[a] (9.214)	34.41[b] (6.457)	71.80[c] (22.682)	70.84[c] (23.757)

[abcd] Row means with different superscripts differ significantly ($P<0.05$)

Grassveld had a higher average manganese concentration for year 2 compared to year 1. Ranteveld had similar average manganese concentrations for year 1 and year 2. Ranteveld had higher average manganese concentrations compared to Grassveld for both years.

There was a seasonal effect of higher average manganese concentrations found during the dry season in the Ranteveld. The average manganese concentration over the two year period for each month was shown in Figure 25. Figure 25 showed higher ($P<0.05$) manganese concentrations for Ranteveld for all of the months except for January and February. The manganese concentration for Grassveld was fairly constant throughout the trial period with only February being higher ($P<0.05$) than any other month within Grassveld.

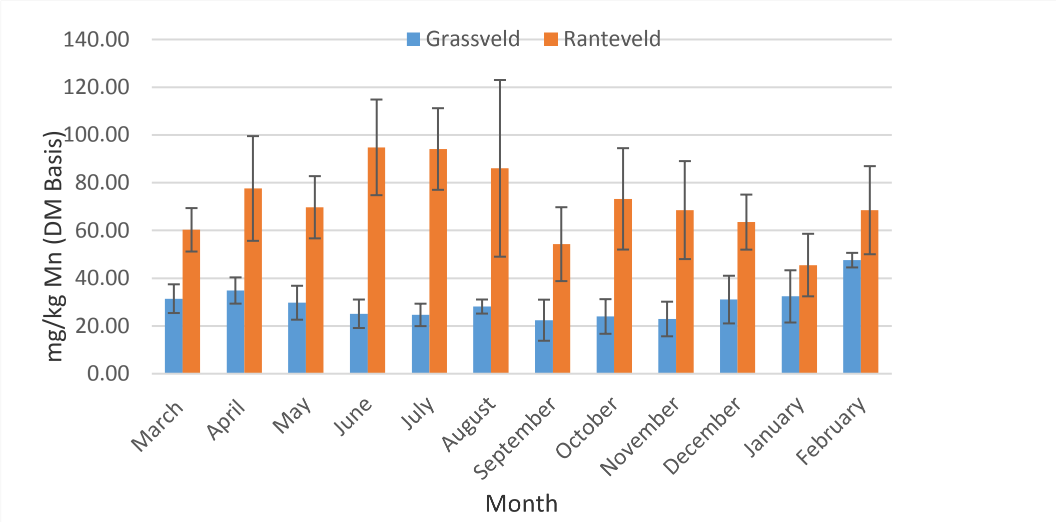

Figure 25 The monthly average iron concentration on a dry matter basis over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

Figure 26 showed the concentration of manganese to sufficient to supply in the requirements as set by the NRC (2007) for a 60kg lactating ewe, producing 0.58kg of milk per day irrespective of intake except for lower intake levels during September and October in the Grassveld.

The levels of manganese in this trial is similar to that suggested by NRC (2007) and well below the maximum tolerable concentration of 2000mg/kg DM as given by NRC (2005). Evidence suggest that high dietary levels of calcium reduces the bio-availability of manganese to ruminants (Spears, 2003).

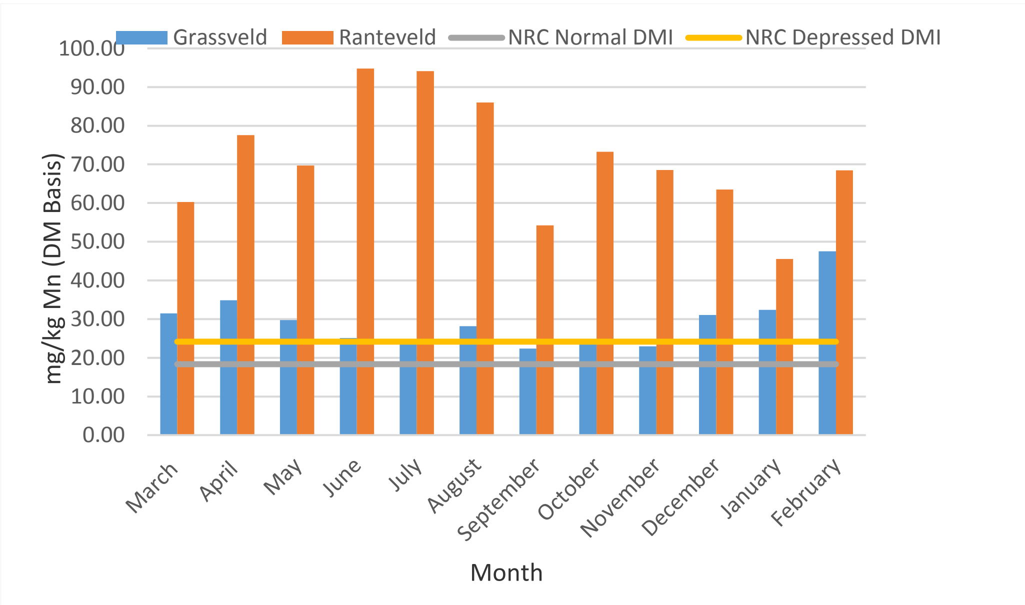

Figure 26 Average monthly manganese concentration (mg/kg) on a dry matter basis for Grassveld and Ranteveld over the two year trial period compared to the NRC manganese concentration requirement for a 60 kg mature ewe in mid lactation with milk production of 0,58kg/day at dry matter intake levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day (NRC, 2007)

4.3.9. Zinc (Zn)

The zinc concentrations for this trial is given in Table 12. The highest concentration of zinc recorded during this trial is for February of year 2 in Ranteveld with a concentration of 27.31 mg/kg on a DM basis. The lowest concentration for zinc recorded is in September of year 1 in Grassveld with a concentration of 8.23 mg/kg on a DM basis.

The zinc concentrations in Grassveld were similar between year 1 and year 2, except for June, December and February. Year 2 had higher concentrations for June and December compared to year 1. February of year one had the highest recorded zinc concentration for the trial period. This was due to the green growth after good rains in the period just before February. In the Ranteveld year 1 had higher zinc concentrations for March, July and September with year 2 having higher concentrations for November, January and February.

Year 1 had significant differences for all the months with Ranteveld showing the higher zinc concentrations for these months except for February where Grassveld had a higher zinc concentration than the Ranteveld. In year 2 Ranteveld had significantly higher zinc concentrations for all the months except March and December which showed similar values for Grassveld and Ranteveld.

Table 12 The zinc concentration (mg/kg) on a dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

	Grassveld		Ranteveld	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2 (±SD)**
March	17.00^{a} (2.164)	16.67^{a} (1.035)	23.48^{b} (1.515)	18.05^{a} (1.948)
April	13.34^{a} (4.330)	13.55^{a} (1.038)	22.84^{b} (1.506)	20.36^{b} (2.213)
May	10.24^{a} (1.875)	11.64^{a} (0.642)	18.71^{b} (1.674)	17.56^{b} (0.962)
June	8.55^{a} (0.529)	13.84^{b} (1.401)	18.50^{c} (2.972)	18.61^{c} (1.608)
July	10.91^{a} (0.860)	12.49^{a} (0.639)	21.95^{c} (2.746)	17.18^{b} (2.024)
August	11.38^{a} (1.270)	13.03^{ab} (0.788)	14.84^{bc} (3.210)	17.33^{c} (1.294)
September	8.23^{a} (0.648)	11.13^{a} (1.615)	23.63^{c} (1.129)	16.52^{b} (0.730)
October	8.73^{a} (0.774)	9.33^{a} (0.612)	17.70^{b} (1.357)	16.84^{b} (1.786)
November	10.29^{a} (0.440)	11.62^{a} (0.886)	15.94^{b} (1.097)	21.09^{c} (0.576)
December	9.44^{a} (0.644)	13.94^{b} (1.153)	17.68^{b} (2.495)	15.66^{b} (0.772)
January	11.32^{a} (0.912)	13.99^{a} (1.247)	18.61^{b} (5.482)	21.90^{b} (2.913)
February	25.14^{b} (3.068)	14.08^{a} (0.345)	15.18^{a} (1.937)	27.31^{b} (1.507)
Average	12.05^{a} (4.885)	12.94^{a}(2.001)	19.09^{b} (3.729)	19.03^{b} (3.430)

^{abcd} Row means with different superscripts differ significantly (P<0.05)

Grassveld had similar average concentrations of zinc for year 1 and year 2. Ranteveld showed no difference between year 1 and year 2 in terms of average zinc concentration. Ranteveld had a higher average zinc concentration compared to Grassveld for both year 1 and year 2 respectively.

Zinc concentrations tended to be lower during the dry winter months for Grassveld. Zinc concentrations remained fairly constant with little seasonal effect in Ranteveld. Figure 27 showed the average monthly zinc concentrations for the trial period with differences ($P<0.05$) between Grassveld and Ranteveld for all of the months except for March and February. Ranteveld had higher ($P<0.05$) average zinc concentrations for all of the months that differed.

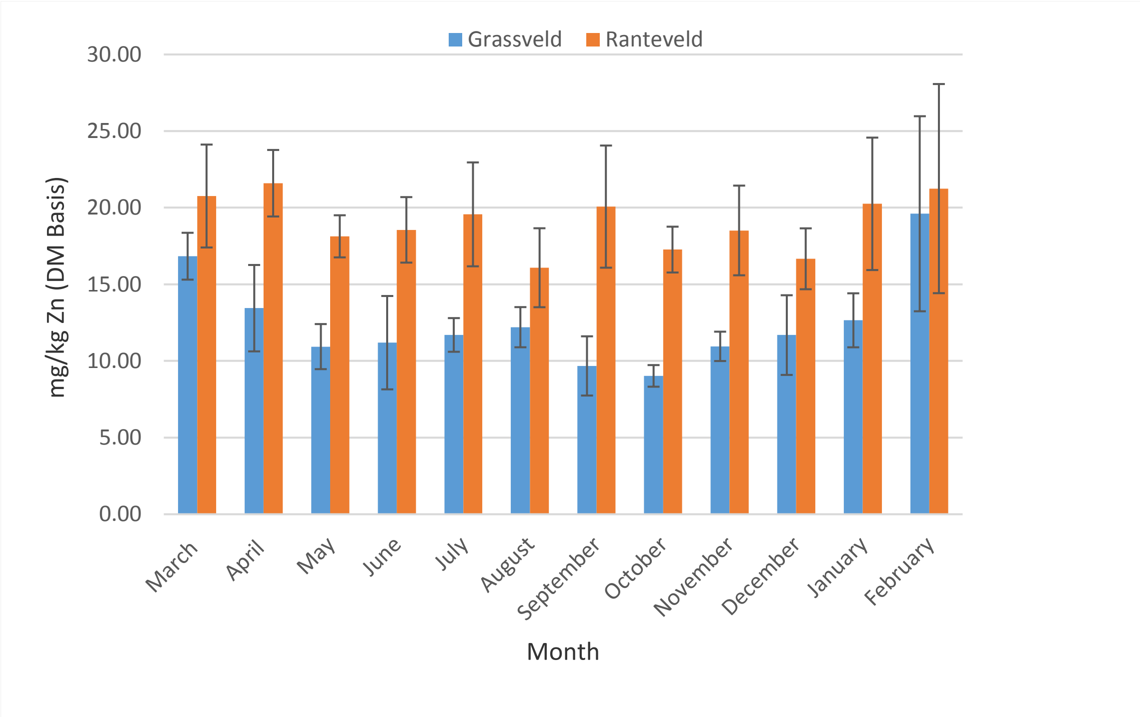

Figure 27 The monthly average zinc concentration on a dry matter basis over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae.

Figure 28 shows the low concentrations of zinc for the samples collected over the trial period. The zinc concentrations are far lower than the recommendations of the NRC (2007) for a lactating ewe of 60kg producing 0.58kg of milk with a normal DMI of 2.68% BW.

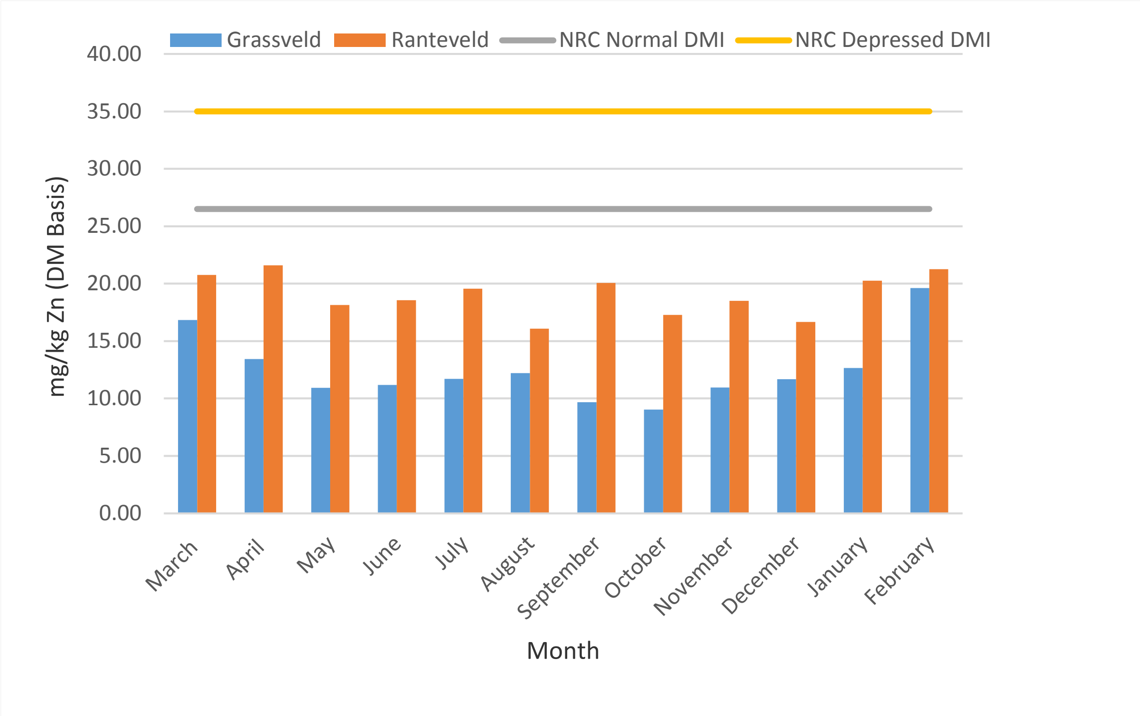

Figure 28 Average monthly zinc concentration in on a dry matter basis for Grassveld and Ranteveld over the two year trial period compared to the NRC zinc concentration requirement for a 60 kg mature ewe in mid lactation with milk production of 0,58kg/day at dry matter intake levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day (NRC, 2007)

Zinc supplementation would be necessary to achieve the recommended zinc intake. Grassveld will require larger amounts of zinc especially during the dry winter months when depressed intake may further worsen the shortfall of zinc supplied by the grazing. Low levels of zinc intake may lead to lower growth rates and depressed reproductive performance (Masters, 1996). Zinc bioavailability can be further reduced due to the high levels of calcium found in the diet and drinking water competing for absorption sites on the metallothionein which binds and transports zinc (Cousins, 1996).

4.3.10. Molybdenum (Mo)

Analysis for Molybdenum could not be done due to the low concentrations of Mo in the sampled extrusa. The samples constantly contained molybdenum concentrations lower than 0.01 mg/kg. Molybdenum supplementation is advised for these animals as Anke *et al.,* (1978) found that goat kids suffered from various symptoms including: reduced feed intake, poor growth, reproductive failure and even death when fed a diet containing Mo at a concentration of 0.06 mg/kg. Molybdenum deficiency is characterized by loss of appetite, growth depression and reproductive losses (Anke & Risch, 1989). Loss of appetite may be caused by inefficient fermentation leading of cellulose and may reflect a need of molybdenum by rumen microbes (Sharrif *et al.,* 1990).

4.3.11. *In-vitro* organic matter digestibility (IVOMD)

The *in-vitro* organic matter digestibility for the trial period is shown in Table 13. The highest value recorded was an IVOMD percentage of 72.10, for January of year 1 in the Grassveld. The lowest observed value was 37.89% during June, year 1 on the Grassveld.

Table 13 The *in-vitro* organic matter digestibility (%) on a dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

	Grassveld		Ranteveld	
	Year 1 (±SD)	Year 2 (±SD)	Year 1 (±SD)	Year 2 (±SD)
March	44.86^{a} (4.262)	67.18^{b} (4.519)	58.03^{ab} (2.015)	62.19^{b} (5.112)
April	47.68^{a} (10.058)	58.59^{ab} (5.902)	66.97^{b} (6.321)	71.02^{b} (4.600)
May	53.03^{a} (5.029)	53.90^{a} (4.982)	56.52^{a} (2.687)	61.28^{a} (3.534)
June	37.89^{a} (11.091)	52.96^{b} (9.025)	56.50^{b} (8.349)	54.62^{b} (6.422)
July	51.14^{a} (11.419)	51.38^{a} (8.437)	51.87^{a} (9.119)	71.58^{b} (3.796)
August	49.14^{a} (7.861)	50.24^{a} (12.321)	55.96^{ab} (7.121)	66.36^{b} (4.168)
September	48.51^{a} (10.531)	53.01^{a} (7.615)	54.58^{a} (9.124)	52.87^{a} (8.422)
October	50.78^{a} (11.612)	61.31^{a} (0.845)	55.67^{a} (8.706)	55.04^{a} (8.395)
November	75.55^{b} (2.948)	62.53^{ab} (9.489)	63.55^{ab} (3.663)	59.17^{a} (7.686)
December	69.93^{a} (3.020)	65.76^{a} (4.540)	63.88^{a} (1.375)	61.13^{a} (7.483)
January	72.10^{a} (1.680)	60.82^{a} (5.558)	62.65^{a} (4.431)	66.49^{a} (2.883)
February	70.86^{b} (1.247)	55.69^{a} (6.748)	52.88^{a} (0.797)	70.83^{b} (3.390)
Average	55.96^{a} (13.810)	57.78^{a} (7.520)	58.29^{a} (7.610)	62.71^{b} (8.030)

^{abcd} Row means with different superscripts differ significantly (P<0.05)

For Grassveld there were differences in the IVOMD % for March, June and February between year 1 and year 2. Year 2 had higher values for March and June with year 1 having a higher value for February. This higher value for February in year 1 was due to high rainfall in the weeks prior to sampling leading to the growth of lush green forage. In the Ranteveld year 2 had higher concentrations of IVOMD for July and February.

During year 1 the Ranteveld had higher IVOMD percentages for April and June but lower levels for February compared to Grassveld. In year 2 Ranteveld had significantly higher IVOMD percentages for July, August and February when compared to Grassveld.

There was no difference for Grassveld between years 1 and 2 in terms of the average IVOMD concentration. In the Ranteveld year 1 was lower (P<0.05) than year 2. Year 1 between Grassveld and

Ranteveld was similar. In year 2 Ranteveld had a higher average IVOMD concentration compared to Grassveld.

Faure *et al.,* (1982) showed IVOMD values of 50-67% with an average of 60.67% for Kalahari sand veld. Orange River Broken veld had IVOMD levels of 55-67 % with an average of 60.91%. Els (2000) showed average IVOMD values for a year of 57.455% when Dorper sheep grazed veld dominated by *Stipagrostis* species. The results from these authors were in agreements to the results obtained from this trial.

The average IVOMD values for the trial period is shown in Figure 29.

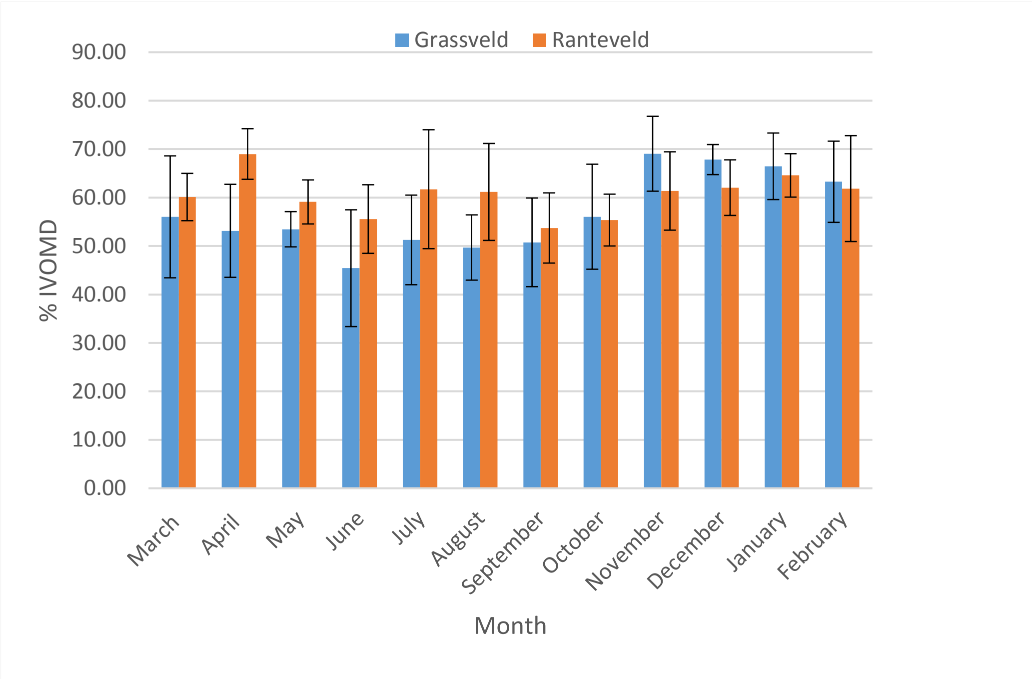

Figure 29 The monthly average *in vitro* organic matter digestibility concentration on a dry matter basis over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

Grassveld and Ranteveld had similar (P>0.05) IVOMD concentrations for all of the months except for April where Ranteveld had a higher (P<0.05) IVOMD concentration compared to Grassveld. Some seasonal variation was found in Grassveld where Nov and January had higher (P<0.05) IVOMD concentrations than May, June, July, August, and September.

4.3.12. Neutral detergent fibre (NDF)

The neutral detergent fibre (NDF) concentrations for the trial varied between years, months and veld types and is shown in Table 14. The NDF values were shown on an organic matter basis to correct for contamination by ash. The highest NDF concentration was 67.76% and occurred in November of year 1 in the Grassveld. The lowest concentration was 31.65% and occurred in year 1, during February in the Grassveld.

Table 14 The neutral detergent fibre concentrations (%) on an organic matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

	Grassveld		Ranteveld	
	Year 1 (±SD)	Year 2 (±SD)	Year 1 (±SD)	Year 2 (±SD)
March	60.45^{c} (1.333)	49.47^{bc} (4.962)	35.13^{a} (3.940)	47.96^{b} (2.173)
April	61.49^{c} (5.257)	56.86^{bc} (1.398)	36.23^{a} (1.280)	45.11^{ab} (2.376)
May	63.86^{c} (4.579)	53.79^{bc} (6.262)	42.40^{ab} (6.275)	33.31^{a} (2.236)
June	66.58^{b} (1.381)	62.17^{b} (7.454)	40.99^{a} (1.129)	39.99^{a} (1.331)
July	53.83^{ab} (14.290)	60.27^{b} (13.783)	42.79^{a} (1.845)	44.17^{a} (2.569)
August	60.27^{b} (1.090)	60.14^{b} (17.032)	47.02^{a} (0.405)	46.61^{a} (4.868)
September	67.13^{c} (2.674)	52.35^{b} (8.244)	34.42^{a} (1.285)	49.44^{b} (1.024)
October	64.37^{b} (2.235)	54.15^{b} (4.672)	37.12^{a} (0.698)	46.44^{b} (3.929)
November	67.76^{b} (1.636)	55.94^{ab} (8.399)	45.56^{a} (1.342)	46.13^{a} (1.253)
December	63.35^{b} (2.835)	65.42^{b} (4.087)	49.19^{a} (1.655)	46.20^{a} (2.140)
January	63.22^{b} (2.646)	66.48^{b} (5.090)	50.74^{a} (1.607)	42.71^{a} (5.481)
February	31.65^{a} (11.832)	65.45^{c} (5.273)	46.58^{a} (2.265)	39.74^{ab} (1.125)
Average	60.33^{b} (10.710)	58.54^{b} (5.850)	42.35^{a} (8.800)	43.98^{a} (4.960)

^{abcd} Row means with different superscripts differ significantly (P<0.05)

The Grassveld year 1 had a higher NDF concentration for September but it had a lower value for February compared to year 2. In the Ranteveld year 2 had higher NDF concentrations for March and September compared to year 1.

Large variation was found between Grassveld and Ranteveld. In year 1 there were 10 months that differed in terms of their NDF concentrations between Grassveld and Ranteveld. Grassveld and Ranteveld had similar NDF concentrations in July of year 1. Ranteveld had higher values for NDF compared to Grassveld only for February of year 1. In year 1 Ranteveld had lower concentrations of NDF for March, April, May, June, August, September, October, November, December and January. During year 2 Ranteveld had lower NDF concentrations for May, June, July, August, December, January and February compared to year 1.

Grassveld had no difference between the average NDF concentrations between the two years. Ranteveld showed no difference between the two years in terms of average NDF concentration. Ranteveld had lower average NDF concentrations compared to Grassveld for both year 1 and year 2.

Figure 30 shows the monthly average NDF concentration over the 2 year trial period.

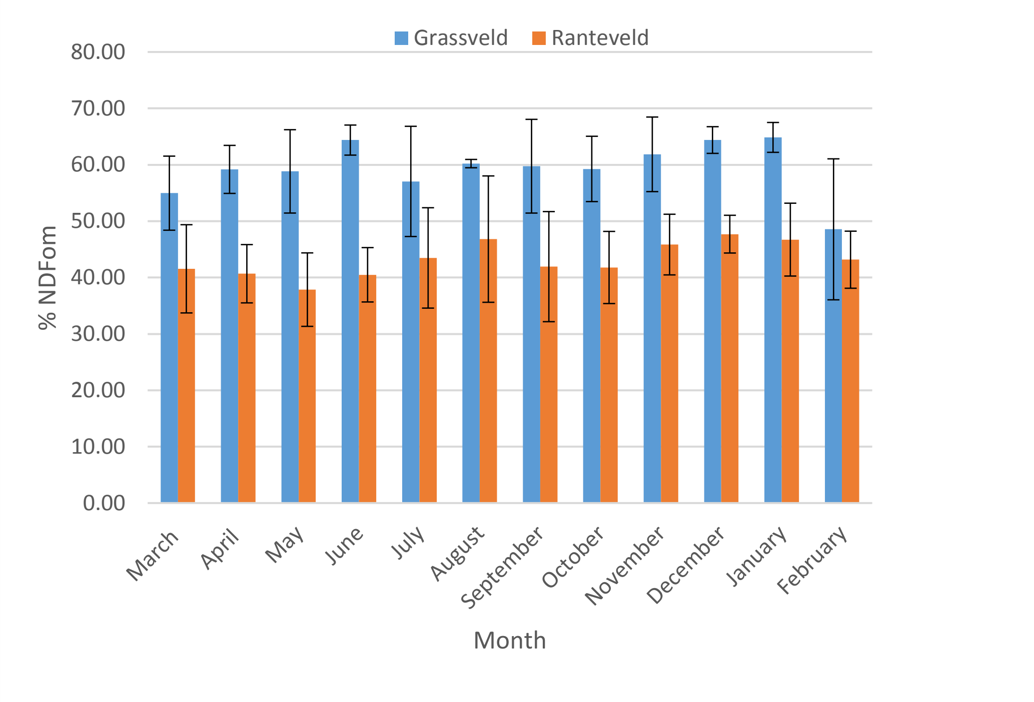

Figure 30 The monthly average neutral detergent fibre concentration on a dry matter basis over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

Grassveld had higher NDF concentrations for April, May, June, August, October, November, December and January. Little seasonal effect was shown for the NDF concentration in the diet selected in both veld types.

4.3.13 *In-vitro* organic matter digestibility: neutral detergent fibre (IVOMD : NDF)

Meissner & Paulsmeier (1995) showed a strong relationship between organic matter intake (gOM.kgBW$^{-0.9}$.d^{-1}) and the ratio of IVOMD : NDF. The IVOMD : NDF ratio is shown in Table 15.

The Ranteveld had higher ratios of IVOMD : NDF for all of the months compared to Grassveld. This means that animals grazing the Ranteveld would have higher levels of organic matter intake compared to animals on the Grassveld. A strong seasonal trend can be observed in the Grassveld, with ratio levels dropping below 1 from April to November. In the summer months (November – March) the ratio remained above 1. This would lead to lower organic matter intakes during the winter. The lower OM intakes coupled with lower plant nutrients including minerals and crude protein would lead to lower production of animals under these range conditions.

Table 15 ***In-vitro*** **organic matter digestibility: neutral detergent fibre ratio for two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae**

	Grassveld	Ranteveld
	Ratio	Ratio
March	1.01	1.45
April	0.89	1.70
May	0.90	1.56
June	0.71	1.37
July	0.90	1.42
August	0.83	1.31
September	0.85	1.28
October	0.95	1.32
November	1.12	1.34
December	1.05	1.30
January	1.02	1.38
February	1.30	1.43

4.3.14. Acid detergent insoluble nitrogen (ADIN)

The acid detergent insoluble nitrogen (ADIN) for the trial collected by sheep with OF are shown in Table 16 The highest recorded ADIN concentration was 29.38 g/kg for August of year 1 in the Grassveld. The lowest ADIN concentration of 4.24 g/kg was found in March of year 1 in the Grassveld. The highest concentration of ADIN for Ranteveld was 28.85 g/kg in December of year 2 with the lowest being 7.48 for February of year 1.

Grassveld had higher ADIN concentrations for August in year 1 compared to year 2. The February ADIN concentration for year 2 was higher than that of year 1 in the Grassveld. In the Ranteveld year 2 had higher ADIN concentrations for May, June, August and December compared to year 1.

When comparing Grassveld and Ranteveld in year 1 it was found that Ranteveld had a higher ADIN concentration for February and Grassveld had a higher ADIN concentration for August. During year 2 Grassveld had a higher ADIN concentration for November with Ranteveld showing higher ADIN concentrations for May, June, August and December.

Table 16 The acid detergent insoluble nitrogen (g/kg) on a dry matter basis of two veld types per month, over a two year period in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae.

	Grassveld		Ranteveld	
	Year 1 (±SD)	Year 2 (±SD)	Year 1 (±SD)	Year 2 (±SD)
March	4.24[a] (0.753)	8.86[a] (1.882)	8.35[a] (2.859)	11.49[a] (0.696)
April	9.14[a] (0.193)	10.41[a] (2.171)	7.69[a] (1.724)	17.44[a] (2.510)
May	15.93[a] (4.150)	18.32[a] (3.514)	12.60[a] (4.998)	28.16[b] (3.231)
June	12.91[a] (2.661)	14.41[a] (3.041)	13.11[a] (3.126)	30.64[b] (1.634)
July	11.63[a] (4.904)	13.47[a] (2.035)	16.82[a] (2.541)	21.03[a] (3.269)
August	29.38[b] (8.381)	16.17[a] (1.813)	12.01[a] (1.102)	24.29[b] (7.840)
September	17.86[a] (4.263)	8.04[a] (1.258)	9.04[a] (2.726)	10.08[a] (1.412)
October	9.47[a] (1.172)	6.73[a] (1.445)	9.27[a] (0.980)	10.74[a] (5.091)
November	13.03[ab] (1.878)	22.58[b] (4.037)	10.77[a] (2.144)	9.72[a] (2.653)
December	12.02[a] (1.737)	13.88[a] (3.147)	8.61[a] (1.096)	28.85[b] (3.423)
January	11.49[a] (8.904)	13.42[a] (3.821)	9.55[a] (0.381)	12.10[a] (0.788)
February	4.67[a] (2.032)	14.38[b] (0.999)	7.48[ab] (0.463)	16.44[b] (2.790)
Average	12.65[a] (7.340)	16.28[b] (13.130)	10.44[a] (3.440)	18.42[b] (8.230)

[abcd] Row means with different superscripts differ significantly ($P<0.05$)

Grassveld had higher average ADIN concentrations for year 2 compared to year 1. Ranteveld also showed higher average ADIN concentrations during year 2. The average ADIN concentrations in Ranteveld and Grassveld were similar for year 1. Year 2 also showed similar average ADIN concentrations for Grassveld and Ranteveld.

Higher concentrations of ADIN leads to lower crude protein digestibility. This can lead to more pronounced crude protein deficiency especially in the dry periods where low crude protein concentrations are already limiting animal production (Hitz *et al.*, 1997). Detmann *et al.*, (2006) showed that ruminants could digest a portion of the ADIN fraction and that ADIN can be used as an indicator but not a predictor of nitrogen compounds potential digestibility.

4.3.15. Energy

The calculated metabolizable energy (ME) is shown in Table 17. The lowest calculated available ME was for June year 1 in Grassveld with a ME of 5.38 MJ/kg. The highest ME recorded was for November, year 1 in Grassveld at a concentration of 10.71 MJ/kg.

The ME was calculated by using the following formula:

ME (MJ/kg DM) = 0.82 x (((2.4CP) + (3.9 x EE) + 1.8(100 – Ash – CP – EE)) x IVOMD/1000 (Robinson *et al.,* 2004).

Where: ME = Metabolisable Energy

CP = Crude Protein on a DM Basis (g/100g)

EE = Ether Extract on a DM basis (g/100g)

Ash = Ash (g/100g) on a DM basis

IVOMD = *In vitro* Organic Matter Digestibility (g/100g) on a DM basis

Table 17 The average metabolisable energy concentration (MJ/kg) on a dry matter basis, over a two year period, as quantified in grazing sheep, for two veld types in the Northern Cape

	Grassveld		Ranteveld	
	Year 1 (±SD)	Year 2 (±SD)	Year 1 (±SD)	Year 2 (±SD)
March	6.44^{a} (0.67)	9.41^{b} (0.448)	7.84^{ab} (0.323)	8.62^{b} (0.784)
April	6.77^{a} (1.42)	8.26^{ab} (0.771)	8.78^{ab} (0.919)	9.93^{b} (0.774)
May	7.41^{a} (0.85)	7.22^{a} (0.527)	7.78^{a} (0.735)	8.30^{a} (0.477)
June	5.38^{a} (1.59)	7.42^{ab} (1.303)	7.78^{b} (1.168)	7.34^{ab} (0.985)
July	7.19^{a} (1.61)	7.19^{a} (1.361)	6.88^{a} (1.279)	9.69^{b} (0.481)
August	6.97^{a} (1.07)	7.10^{ab} (1.972)	7.53^{ab} (1.072)	9.20^{b} (0.499)
September	6.90^{a} (1.49)	7.40^{a} (1.088)	7.28^{a} (1.350)	7.20^{a} (1.156)
October	7.18^{a} (1.61)	8.57^{a} (0.063)	7.31^{a} (1.222)	7.28^{a} (1.116)
November	10.71^{b} (0.55)	8.71^{ab} (1.442)	8.72^{ab} (0.457)	8.38^{a} (1.132)
December	10.10^{a} (0.50)	9.45^{a} (0.769)	8.75^{a} (0.226)	8.28^{a} (0.943)
January	10.21^{a} (0.47)	8.68^{a} (0.454)	8.52^{a} (0.614)	9.06^{a} (0.502)
February	10.11^{c} (0.45)	7.94^{ab} (0.975)	7.27^{a} (0.144)	9.79^{bc} (0.440)
Average	7.95^{a} (1.984)	8.11^{ab} (1.114)	7.87^{a} (1.092)	8.59^{b} (1.167)

^{abcd} Row means with different superscripts differ significantly (P<0.05)

In Grassveld March of year 2 had a higher ME concentration compared to year 1, with February of year 1 having a higher ME value than February year 2. For the Ranteveld a similar consistency was observed with only July and February of year 2 showing higher ME concentrations compared to year 1.

Low variation was found between Grassveld and Ranteveld for year 1, only June and February showed differences in ME concentration between Grassveld and Ranteveld. In June, Ranteveld had a higher ME concentration and in February the ME concentration in Grassveld was higher. Year 2 showed a difference for July, here Ranteveld had a higher ME concentration compared to Grassveld. All of the other months showed similar ME concentrations.

The average ME concentrations for Grassveld was the same for year 1 and year 2. Ranteveld also showed similar average ME concentrations for year 1 and year 2. Grassveld and Ranteveld had similar concentrations for year 1. In year 2 Grassveld and Ranteveld also had similar concentrations.

Figure 31 showed the average ME concentrations over the trial period. Very little seasonal variation could be observed for Ranteveld. Grassveld showed higher ME concentrations for November, December and January when compared to May, June, July, August and September. No differences could be observed between the two veld types.

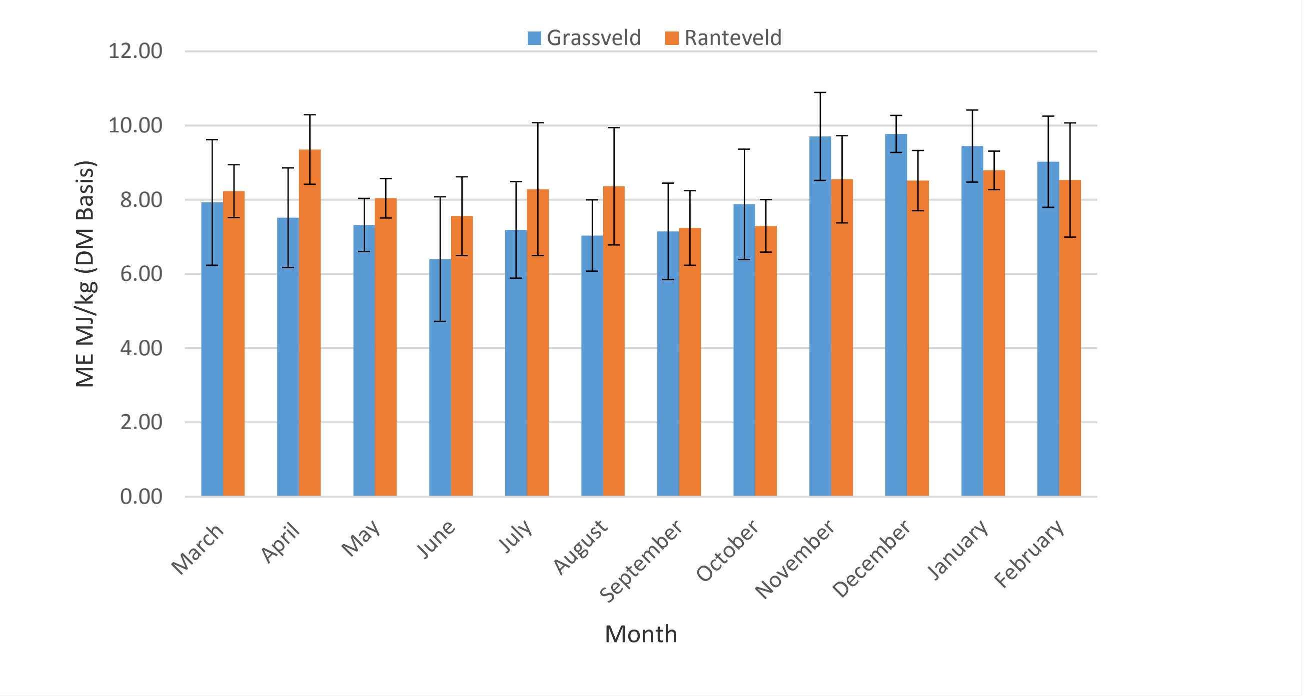

Figure 31 The monthly average metabolisable energy concentration on a dry matter basis, over a two year period of two veld types in the Northern Cape as quantified in grazing sheep fitted with oesophageal fistulae

In Figure 32 the ME as required for lactation as predicted by the NRC, (2007) is graphically displayed compared to the average ME of the two camps for the different months. From this Figure it can be seen that there is a shortage of energy during the winter months. It should be noted that these values are given for penned animals and as shown by Graham (1964) the energy expenditure of animals grazing relatively small flat camps could be as much as 40% higher than for penned animals. Graham (1964) noted that sheep in hilly pasture and a long way from water could face major energy expenditure in order to graze.

Shortage of energy leads to various reductions of production and efficiencies NRC, (2007). Lower energy intake leads to reduced growth and immune response (Singh *et al.,* 2013). Reductions in milk production was observed by Robinson (1990), even at high protein levels energy was a limiting factor in total milk production.

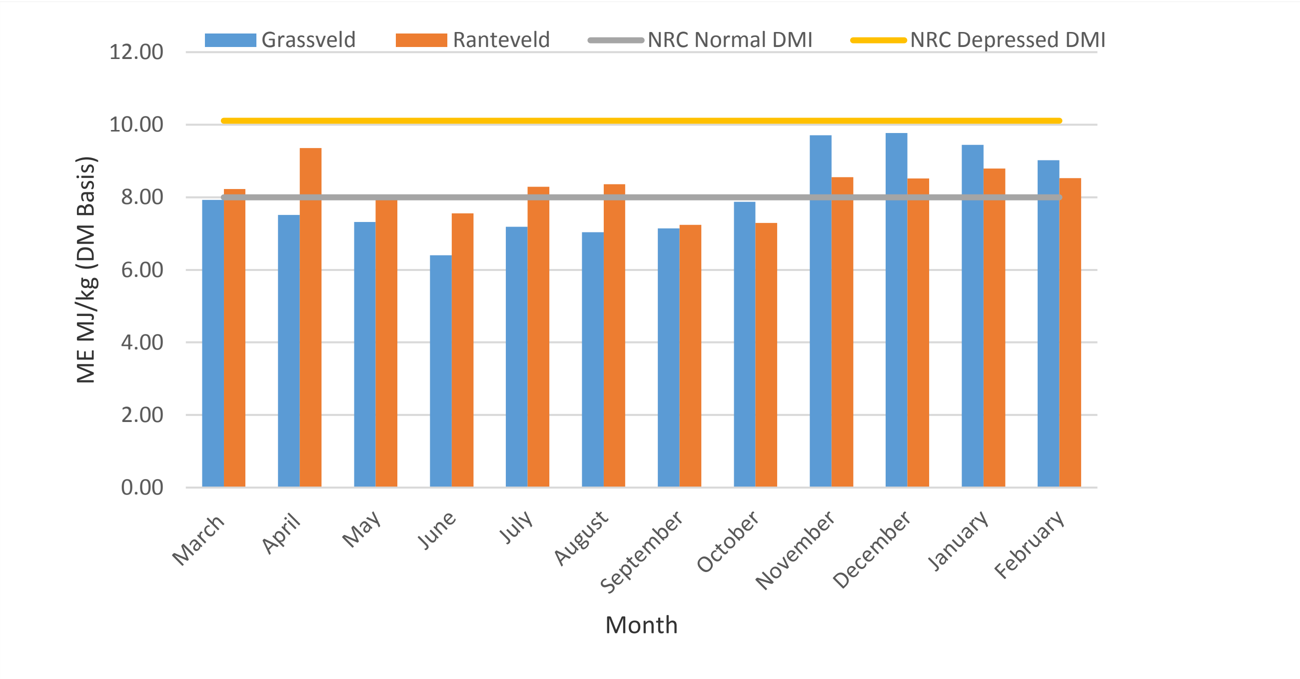

Figure 32 Average monthly metabolisable energy concentration (MJ/kg) on a dry matter basis for Grassveld and Ranteveld over the two year trial period compared to the NRC metabolisable energy concentration requirement for a 60 kg mature ewe in mid lactation with milk production of 0,58kg/day at dry matter intake levels of 2.68% of body weight (Normal) and 2% of body weight (Depressed) per day (NRC, 2007)

4.4. BLOOD METABOLITES (BUN)

Blood urea nitrogen (BUN) levels for 11 months of year 1 were shown in Table 18. No BUN results was obtainable for the other months of the trial due to the lack of transport of the freshly centrifuged samples to a Pathcare™ laboratory.

Table 18 The average blood urea nitrogen concentration in mmol/L, for sheep grazing two veld types in the Northern Cape

	Grassveld	Ranteveld
	Average (±SD)	Average (±SD)
March		
April	4.80^{a} (1.089)	5.10^{a} (0.648)
May	2.08^{a} (0.050)	4.85^{b} (0.676)
June	1.90^{a} (0.271)	3.68^{b} (0.544)
July	2.13^{a} (0.386)	2.70^{a} (0.566)
August	2.08^{a} (0.222)	2.33^{a} (0.350)
September	1.93^{a} (0.457)	2.18^{a} (0.250)
October	1.95^{a} (0.520)	2.98^{b} (0.150)
November	1.65^{a} (0.635)	2.35^{b} (0.507)
December	2.35^{a} (0.387)	3.13^{b} (0.957)
January	2.53^{a} (0.450)	6.93^{b} (0.754)
February	7.80^{a} (0.845)	8.15^{a} (0.819)
Average	2.83^{a} (1.854)	4.03^{b} (2.006)

[ab] Row means with different superscripts differ significantly (P<0.05)

Ranteveld had a higher BUN concentration for May, June, October, November, December and January when compared to Grassveld. The highest BUN concentration was observed in February in the Ranteveld with a BUN concentration of 8.15 mmol/L. This high level coincided with high rainfall in the prior month (Figure 7) leading to high crude protein values (Table 5). The lowest concentration was observed in June in the Grassveld with a BUN concentration of 1.90mmol/L. For June low concentrations of crude protein was recorded (Table 5), most probably due to low rainfall and frost.

Figure 33 shows the monthly BUN levels as determined in the trial. The suggested minimum critical levels for where protein supplementation would have a beneficial effect as stated by Preston *et al.* (1965), is 2.5 mmol.l^{-1} for grazing cattle. During the dry season from May to December (Figure 7) sheep in Grassveld had BUN of lower than 2.5 mmol.l^{-1}. This indicated that crude protein intake dropped and that protein supplementation could be beneficial. During the wet season months of April, January and February the average BUN levels raised above this critical level showing that sufficient protein was available.

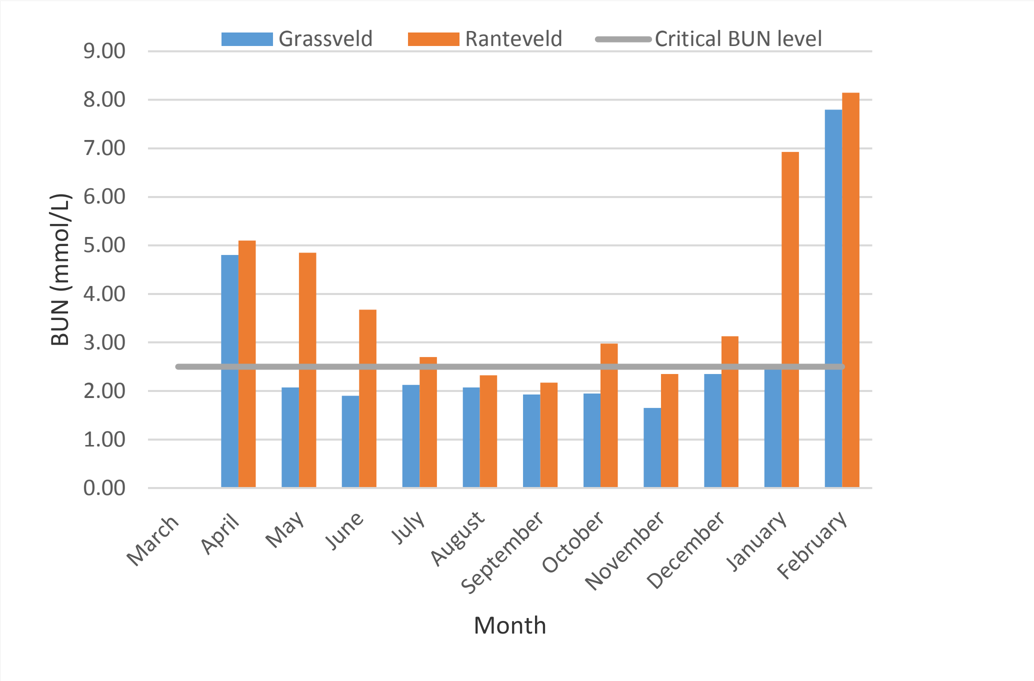

Figure 33 Blood urea nitrogen concentrations for Grassveld and Ranteveld over a one year period as quantified in grazing sheep (mmol/L) with a critical minimum blood urea nitrogen level of 2.5 mmol/L as proposed by Preston *et al.* (1965) illustrated as a line

For Ranteveld the BUN level stayed closer to the suggested 2.5mmol/L. At the commencement of the dry season in May the BUN did not drop as quickly for Ranteveld as compared to Grassveld. This was due to the higher crude protein concentration as shown by the oesophageal extrusa samples in Table 5. During the later dry season from July to December the BUN concentrations dropped below the suggested minimum level of 2.5 mmol/L. As soon as good rains returned in January and February the BUN concentrations rose as high as 6.93 and 8.15mmol/L respectively. BUN levels serve as an indicator of the crude protein intake of animals (Hammond, 1997; Huntington & Archibeque, 2000 and Huntington *et al,.* 2001). Hammond *et al.,* (1993) showed that steers had a positive reaction in terms of ADG when protein supplements were fed when BUN levels ranged from 6.2 to 9 mg/100ml (2.1 to 3.3 mmol/L). At levels between 9 and 15 mg/100ml (3.2 to 5.4 mmol/L) protein supplementation had less effect on the animals ADG. When BUN levels reached 9.6 mg/100ml (3.4 mmol/L) and higher a positive response was found with energy supplementation. These high BUN levels were indicative of high dietary protein : energy ratios and a positive reaction to energy supplementation was expected (Hammond *et al.,* 1993). In order to test BUN levels as a nutritional indicator for diet CP, regressions were determined in Figure 34 and Figure 35.

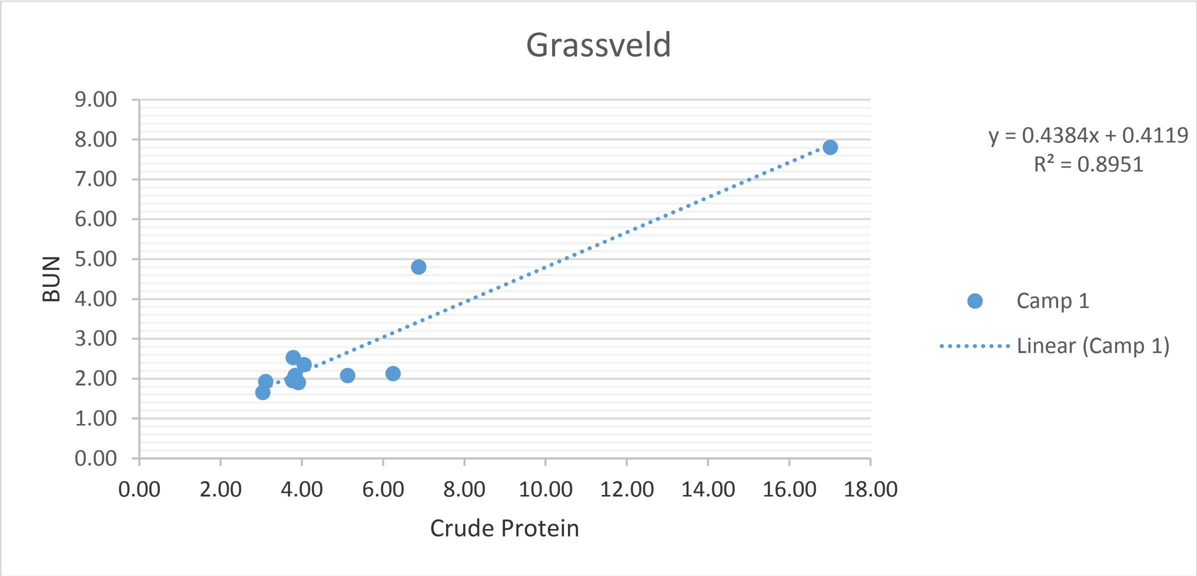

Figure 34 Blood urea nitrogen correlation to crude protein for Grassveld in the Northern Cape as quantified in grazing sheep (R^2 = 0.8951)

In Grassveld the relationship between BUN and diet CP was very strong with an R^2 = 0.8951. This indicates that BUN could be used as nutritional indicator or as a management tool to make decisions on protein supplementation programs.

In Ranteveld there was a trend to predict diet CP with BUN levels. The R^2 value for the regression in Ranteveld was 0.446 as shown in Figure 33. This does not show a strong relationship.

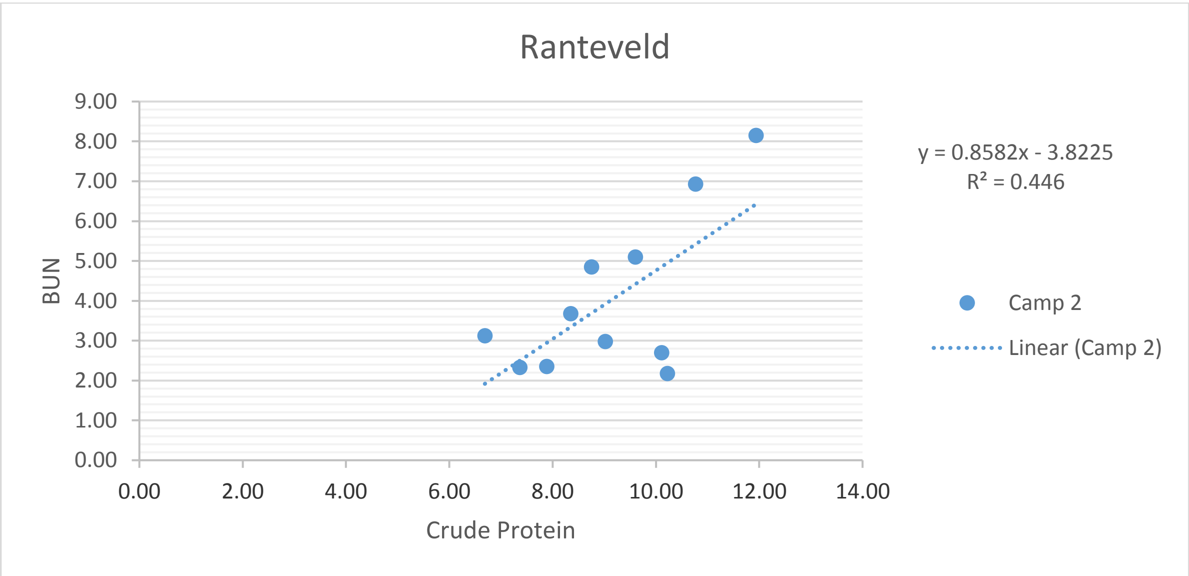

Figure 35 Blood urea nitrogen correlation to crude protein for Ranteveld in the Northern Cape as quantified in grazing sheep (R^2 = 0.446)

Strong relationships between crude protein intake and BUN was found for lambs fed on a diet containing 50% roughage with varying levels of crude protein (Simpson, 2000). Roodt (2012) found a strong relationship between diet crude protein and BUN concentrations for cattle grazing natural pasture in Namibia

4.5. RUMEN LIQOUR

4.5.1. Ammonia-N

The rumen ammonia-N (NH_3-N) concentrations are shown in Table 19 and Figure 34. The lowest recorded concentration for rumen NH_3-N was 1.96 mg/100ml during June of year 1 in Ranteveld. The highest recording was 14.66mg/100ml for January in year 2, in Ranteveld.

Table 19 The average rumen ammonia-nitrogen concentrations for sheep grazing two veld types in the Northern Cape (mg NH_3-N / 100ml)

	Grassveld		Ranteveld	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2 (±SD)**
March	3.74^a (0.530)	3.58^a (0.739)	4.36^a (0.685)	4.41^a (0.789)
April	5.73^a (1.452)	6.46^a (1.051)	7.31^a (1.772)	7.84^a (0.980)
May	5.13^{ab} (1.241)	6.11^b (0.237)	3.35^a (1.548)	3.36^a (0.344)
June	2.24^a (0.526)	2.51^a (0.087)	1.96^a (0.712)	1.99^a (1.041)
July	2.41^a (1.085)	2.77^a (0.533)	2.38^a (1.233)	2.61^a (0.629)
August	2.28^a (0.761)	2.79^a (1.107)	3.48^a (0.945)	4.09^a (1.237)
September	3.10^a (0.563)	3.62^a (0.284)	2.01^a (0.588)	2.33^a (0.314)
October	2.92^a (0.715)	3.39^a (0.340)	2.04^a (0.957)	2.34^a (0.394)
November	2.73^a (0.261)	3.33^a (1.093)	3.06^a (0.352)	3.70^a (1.376)
December	6.69^a (1.942)	8.49^a (2.134)	10.92^b (2.418)	13.47^c (2.628)
January	7.26^a (0.859)	8.91^a (1.790)	12.42^b (1.100)	14.66^c (2.274)
February	8.21^a (1.561)	9.40^a (0.312)	7.93^a (1.989)	7.84^a (0.253)
Average	4.37^a (2.300)	5.11^{bc} (2.789)	5.10^b (3.604)	5.72^c (4.398)

^{abcd} Row means with different superscripts differ significantly ($P<0.05$)

Grassveld had no significant differences between year 1 and year 2. Ranteveld had significantly higher rumen NH^3-N concentrations during year 2 for December and January compared to year 1.

During year 1 the Ranteveld had higher rumen NH_3-N concentrations than Grassveld for December and January. During year 2 Grassveld had a higher concentration of rumen NH_3-N for May compared to Ranteveld. Ranteveld showed higher concentrations of rumen NH_3-N for December and January of year 2 compared to Grassveld.

Grassveld had a lower average rumen NH_3-N concentration for year 1 compared to year 2. Ranteveld also had a lower average rumen NH_3-N concentration for year 1 compared to year 2. In year 1 Grassveld had a lower average rumen NH_3-N concentration compared to Ranteveld of year 1.During year 2 there was no difference between the average rumen NH_3-N concentration of Grassveld and Ranteveld.

There was a very strong seasonal effect with the rumen NH_3-N concentration levels. As soon as the rain stopped and the first frost occurred by the end of May the rumen NH_3-N levels dropped ($P<0.05$) in both camps. In contrast when the rains returned in December, January and February the rumen NH^3-N levels were higher ($P<0.05$) that the preceding winter months (May – November). Figure 36 shows the average rumen NH_3-N concentrations for the trial period. Ranteveld had a higher ($P<0.05$) rumen NH_3-N concentration within the same month compared to Grassveld only during April, December and January.

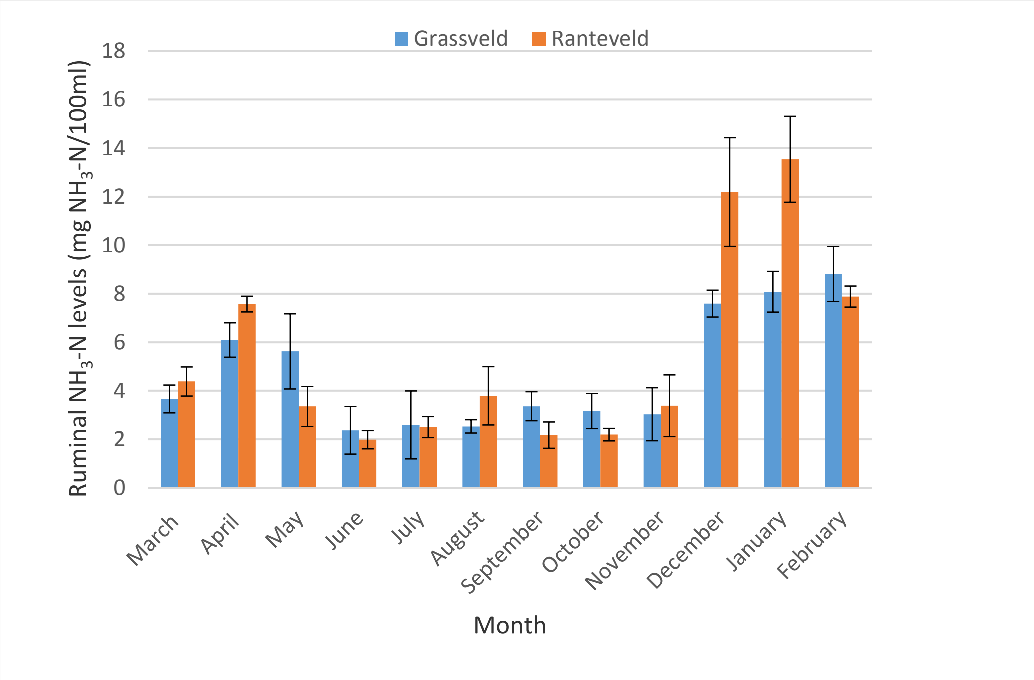

Figure 36 The average rumen ammonia-nitrogen concentrations for sheep grazing two veld types in the Northern Cape (mg NH_3-N / 100ml)

During the winter months of May to October the concentration of rumen NH_3-N was close to minimum concentration postulated by Satter & Roffler (1977) and Slyter *et al.,* (1979) for the effective production of rumen microbes. Detmann (2009) proposed rumen NH_3-N concentrations of 8mg/100ml for the optimal utilization of NDF. During the winter months the levels were constantly below the level of 8mg/100ml, suggesting that the rumen NH_3-N concentration was too low to utilize the NDF on offer effectively. The supplementation of a nitrogen containing lick during these times might lead to increased ruminal NH_3-N levels and thus increased NDF utilization and production (Roodt, 2012). Perdok *et al.,* (1987) suggested rumen NH_3-N levels higher than 20mg/100ml are required to obtain maximal levels of rice straw intake by steers. Detmann (2009) proposed that a rumen NH_3-N level of 15mg/100ml would lead to maximum levels of dry matter intake by steers fed *Brachiaria decumbens* hay. During this trial rumen NH_3-N concentrations above 15mg/100ml were not recorded.

4.5.2. Volatile Fatty Acids

The total volatile fatty acid concentrations are showed in Table 20. The values varied between 80.06 - 148.57mmol/L. The highest concentrations were found during the green periods after good rainfall had occurred with January of year 2, in the Ranteveld reaching a level of 148.57mmol/L. This was significantly higher than any other concentration for the month of January. The lowest levels where during March year 1, in Grassveld.

Table 20 The average total volatile fatty acid concentrations for sheep grazing two veld types in the Northern Cape (mmol/L)

	Grassveld		Ranteveld	
	Year 1 (±SD)	Year 2 (±SD)	Year 1 (±SD)	Year 2 (±SD)
March	80.1^{a} (5.68)	84.9^{ab} (0.39)	93.2^{ab} (4.95)	97.8^{b} (4.03)
April	107.0^{a} (5.46)	121.2^{ab} (8.21)	120.4^{ab} (5.56)	128.3^{b} (9.31)
May	111.5^{a} (6.29)	123.2^{a} (5.57)	104.0^{a} (7.91)	113.1^{a} (5.80)
June	93.2^{a} (6.35)	100.7^{a} (11.18)	94.8^{a} (6.85)	102.1^{a} (13.91)
July	96.4^{a} (6.11)	106.5^{a} (4.72)	93.6^{a} (8.69)	99.3^{a} (6.94)
August	95.6^{a} (4.72)	106.3^{a} (4.33)	103.2^{a} (5.02)	110.6^{a} (6.92)
September	106.7^{ab} (11.67)	117.8^{b} (3.51)	100.8^{a} (13.71)	109.4^{ab} (5.19)
October	87.1^{a} (8.75)	94.0^{ab} (12.50)	103.2^{b} (11.02)	112.7^{b} (16.35)
November	84.7^{a} (4.23)	93.1^{a} (8.55)	115.1^{b} (5.26)	127.9^{b} (9.90)
December	107.7^{a} (11.30)	121.7^{ab} (11.23)	128.3^{bc} (14.74)	143.2^{c} (13.94)
January	112.6^{a} (8.13)	125.8^{ab} (8.77)	132.4^{b} (10.42)	148.6^{c} (10.98)
February	118.9^{a} (9.43)	128.3^{a} (5.71)	118.7^{a} (11.94)	124.2^{a} (6.53)
Average	100.1^{a} (13.74)	110.3^{c} (16.42)	109.0^{b} (14.77)	118.1^{d} (18.18)

^{abcd} Row means with different superscripts differ significantly ($P<0.05$)

Variation between years for Grassveld showed no differences for total VFA concentrations. In the Ranteveld only January of year 2 was higher compared to year 1, with all the other months showing similar values for the trial period.

During year 1 Ranteveld had higher concentrations of total VFA for October, November, December and January compared to Grassveld. In year 2, Ranteveld had higher concentrations of VFA for November, December and January compared to Grassveld.

Grassveld had a higher average VFA concentration during year 2 compared to year 1. Ranteveld also had higher average VFA concentration during year 2 compared to year 1. There were differences between Ranteveld and Grassveld in terms of average VFA concentrations for both year 1 and year 2 respectively.

The total VFA followed a reasonably strong trend of lower production for both camps during the dry months from June to November as seen in Figure 37. This can be expected as the quality of the forage dropped during this dry period, with minor green flushes if there was a shower of rain. The peak production of VFA's was in the green months of December to April with the exception of March. The reason for the lower production of VFA's in March for both camps cannot be fully explained. Ranteveld had higher (P<0.05) concentrations of VFA for April, November, December and January.

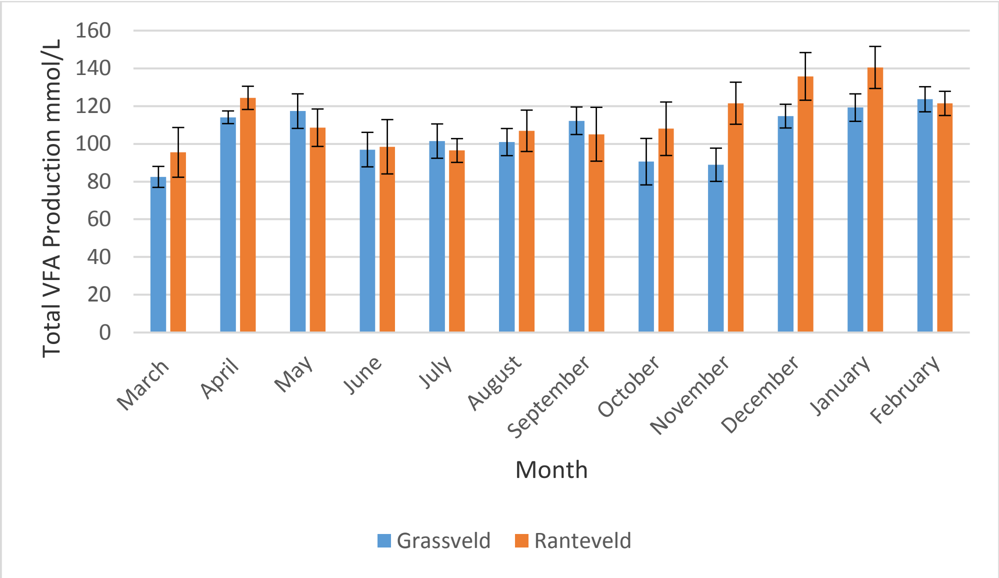

Figure 37 The average total volatile fatty acid concentrations for sheep grazing two veld types in the Northern Cape (mmol/L)

The percentage contribution of each volatile fatty acid to the total VFA production was remarkably consistent. The total contribution by acetic acid was very high (>70%) this indicates high roughage levels in the diet and also indicates more mature fibre (Thomas & Rook, 1981).The propionic acid levels was also fairly constant with values fluctuating between 19.13 – 26.05%. The levels for butyric acid was very low and only increased during the wetter months when the diet was less fibrous.

Ruminal acetic acid concentrations are reported in Table 21. There were no differences between year 1 and year 2 for any of the months in Grassveld. Ranteveld also showed no difference in the acetic acid concentration for any month between year 1 and year 2.

During year 1 Ranteveld had higher acetic acid concentrations for November and January compared to Grassveld. Ranteveld in year 2 had higher acetic acid concentrations for October, November, December and January compared to Grassveld.

Grassveld had higher average acetic acid concentrations for year 2 compared to year 1. Ranteveld also showed higher average acetic acid concentrations for year 2 compared to year 1. Ranteveld had higher average acetic acid concentrations for year 1 and year 2 respectively, compared to Grassveld.

Table 21 The average acetic acid concentrations for sheep grazing two veld types in the Northern Cape (mmol/L)

	Grassveld		Ranteveld	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2 (±SD)**
March	58.75[a] (4.012)	62.25[ab] (1.203)	67.95[ab] (3.576)	70.70[b] (3.311)
April	78.26[a] (3.473)	88.53[ab] (6.778)	87.29[ab] (3.938)	93.25[b] (7.834)
May	82.86[ab] (5.369)	91.48[b] (4.220)	77.63[a] (6.816)	84.53[ab] (4.449)
June	69.99[a] (3.720)	75.31[a] (5.743)	71.84[a] (3.629)	77.43[a] (7.158)
July	72.27[a] (4.255)	79.93[a] (2.691)	70.88[a] (6.090)	75.14[a] (4.194)
August	72.22[a] (4.003)	80.30[a] (2.535)	72.90[a] (4.506)	77.53[a] (4.193)
September	76.32[ab] (6.959)	83.88[b] (3.518)	71.06[a] (8.068)	76.57[ab] (5.332)
October	63.54[a] (4.746)	68.38[a] (9.341)	74.19[ab] (5.992)	80.53[b] (12.092)
November	61.68[a] (2.965)	67.59[a] (6.184)	86.52[b] (3.360)	96.79[b] (7.538)
December	77.93[a] (7.362)	87.68[a] (8.233)	89.20[ab] (9.677)	98.77[b] (10.535)
January	81.07[a] (7.470)	90.49[ab] (6.732)	92.39[bc] (9.253)	103.12[c] (8.463)
February	85.15[a] (6.866)	91.61[a] (3.668)	84.86[a] (9.134)	89.10[a] (4.179)
Average	73.34[a] (9.493)	80.62[b] (11.429)	78.89[b] (9.630)	85.29[c] (12.044)

[abcd] Row means with different superscripts differ significantly ($P<0.05$)

The percentage contribution of acetic acid to the total VFA was very high. This is to a large extent to the high fibrous diet consumed by the animals as mentioned earlier in Table 14. The lowest % contribution of acetic acid was during December of year 2 in Ranteveld. This corresponds to high rainfall and lower fibre levels in the diets consumed. There is a general trend to lower % contributions to total VFA production during the wetter summer months of December to February.

The highest percentage contribution by acetic acid to total VFA production was during June in Ranteveld. It is interesting to note that the highest contribution of acetic acid is during the dry parts of the year. This is due to low quality and very fibrous diets (Thomas & Rook, 1981). Adams *et al.* (1987) also found higher contribution from acetic acid to the total VFA concentration with the increase in forage maturity.

Figure 38 shows the monthly average of ruminal acetic acid concentrations. Similar concentrations were found for all of the months except for November where Ranteveld had a higher ($P<0.05$) concentration compared to Grassveld.

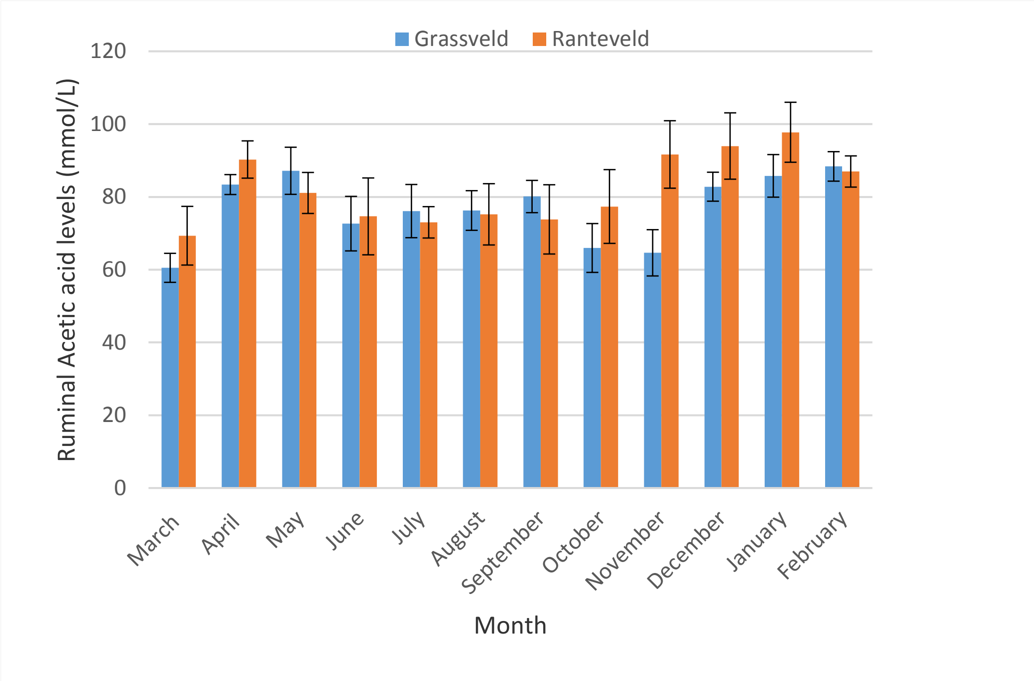

Figure 38 The average acetic acid concentrations for sheep grazing two veld types in the Northern Cape (mmol/L)

The propionic acid concentrations for the trial period is shown in Table 22. The lowest concentration of propionic acid was found in March, year 1 in Grassveld at only 16.52 mmol/L. During the winter month's readings of 20mmol/L or lower was quite common whereas in the summer months levels were closer to 30mmol/L for Ranteveld. The highest concentration was 32.42 mmol/L for January, year 2 in Ranteveld.

There was no significant differences between year 1 and year 2 for any of the months for both Grassveld and Ranteveld.

Ranteveld had higher concentrations of propionic acid for August and December in year 1 compared to Grassveld. Ranteveld had higher concentrations of propionic acid for August, October, December and January in year 2 compared to Grassveld

Grassveld had higher average propionic acid concentrations for year 2 compared to year 1. Ranteveld also showed higher average propionic acid concentrations for year 2 compared to year 1. Ranteveld had higher average propionic acid concentrations for year 1 and year 2 respectively, compared to Grassveld.

Table 22 The average propionic acid concentrations for sheep grazing two veld types in the Northern Cape (mmol/L)

	Grassveld		Ranteveld	
	Year 1 (±SD)	**Year 2 (±SD)**	**Year 1 (±SD)**	**Year 2 (±SD)**
March	16.52[a] (1.233)	17.75[a] (1.216)	19.32[a] (1.097)	20.14[a] (1.351)
April	23.00[a] (1.665)	26.35[a] (1.271)	24.09[a] (1.850)	25.62[a] (1.224)
May	22.81[a] (1.745)	25.34[a] (1.562)	20.51[a] (1.869)	22.51[a] (1.723)
June	20.13[a] (2.417)	22.33[a] (6.060)	18.45[a] (2.943)	19.92[a] (7.565)
July	20.96[a] (1.774)	23.40[a] (1.626)	18.34[a] (2.440)	19.58[a] (2.103)
August	20.20[a] (1.419)	22.65[ab] (2.590)	26.12[bc] (1.618)	28.80[c] (3.389)
September	26.94[a] (5.574)	30.32[a] (2.332)	25.69[a] (6.904)	28.46[a] (2.634)
October	19.95[a] (3.812)	21.80[a] (4.112)	25.14[ab] (4.779)	28.10[b] (5.092)
November	19.54[a] (1.652)	21.71[a] (3.311)	24.42[ab] (2.047)	26.65[b] (4.035)
December	21.78[a] (3.242)	24.50[ab] (2.588)	28.68[bc] (4.119)	32.07[c] (3.008)
January	24.15[a] (1.661)	26.74[a] (1.680)	28.66[ab] (2.473)	32.42[b] (2.020)
February	24.72[a] (2.231)	26.89[a] (3.167)	25.42[a] (2.340)	26.84[a] (3.680)
Average	21.72[a] (3.562)	24.15[b] (4.264)	23.74[b] (4.414)	25.93[c] (5.369)

[abcd] Row means with different superscripts differ significantly ($P<0.05$)

The monthly average propionic concentration is shown in Figure 39. Even though there was variation over months in the concentration of propionic acid, the percentage contribution to the total VFA concentration was more stable over the same period. The contributions of propionic acid varied from 19.07 – 26.05% of total VFA concentration. These levels were very similar to those reported by Topps & Elliot (1964).

There seems to be very little seasonal trend but higher contributions by propionic acid concentration to the total VFA concentration was seen for months of August, November, December and January. This is in contrast to the findings of Adams *et al.* (1987) who reported a decrease in the propionic acid contribution to total VFA concentration as forage becomes more mature. Park *et al.* (1994) and Roodt (2012) found the similar trend of elevated propionic acid concentrations during the dry season compared to lower levels during the wet season.

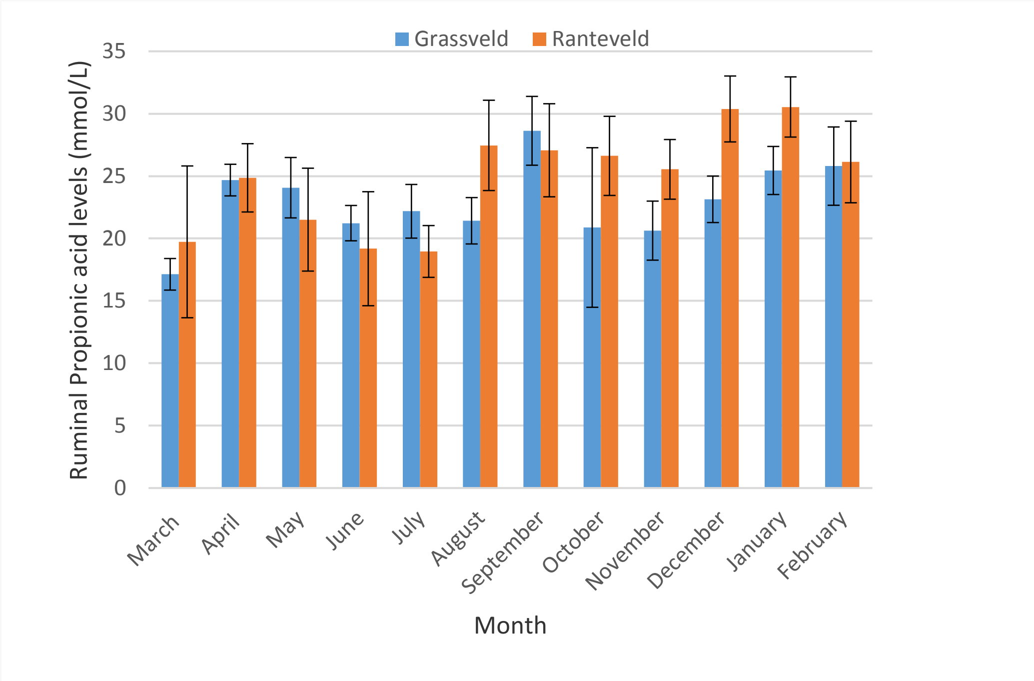

Figure 39 The average propionic acid concentrations for sheep grazing two veld types in the Northern Cape (mmol/L)

The butyric acid concentrations for this trial was very low and is shown in Table 23. The reason being the low starch component in the diet coupled with the high fibre content (Annison *et al.,* 2002). Ranteveld had higher butyric acid concentrations for almost all of the months, excluding September, October, November, December and February of years 1 and 2.

The lowest concentration of butyric acid was found in June, year 2 Grassveld with a concentration of only 1.11 mmol/L. The highest concentration was 6.99mmol/L and this was achieved in January, year 2 in Ranteveld.

Grassveld had different concentrations of butyric acid between year 1 and year 2 for December and January, in both these instances year 2 had the higher concentration. Ranteveld showed differences between year 1 and year 2 for December and January, with year 2 being higher than year 1 in both instances.

In year 1 Ranteveld had higher concentrations compared to Grassveld for March, April, May, June, July, August, December and January. Grassveld had a higher butyric acid concentration than Ranteveld only for October during year 1. In year 2 differences were found between the two veld types for all the months except for February. Grassveld had higher butyric acid concentrations for October and November. Ranteveld had higher butyric acid levels compared to Grassveld for March, April, May, June, July, August, September, December and January of year 2.

Table 23 The average butyric acid concentrations for sheep grazing two veld types in the Northern Cape (mmol/L)

	Grassveld		Ranteveld	
	Year 1 (±SD)	Year 2 (±SD)	Year 1 (±SD)	Year 2 (±SD)
March	1.88[a] (0.221)	1.75[a] (0.210)	2.85[b] (0.212)	2.99[b] (0.253)
April	1.74[a] (0.214)	1.78[a] (0.238)	3.98[b] (0.261)	4.39[b] (0.266)
May	2.13[a] (0.263)	2.29[a] (0.181)	2.86[b] (0.295)	3.01[b] (0.189)
June	1.21[a] (0.275)	1.11[a] (0.208)	2.09[b] (0.373)	2.14[b] (0.299)
July	1.25[a] (0.138)	1.16[a] (0.265)	1.88[b] (0.163)	1.97[b] (0.343)
August	1.26[a] (0.163)	1.21[a] (0.179)	2.31[b] (0.192)	2.47[b] (0.268)
September	1.81[a] (0.337)	1.86[a] (0.139)	2.31[ab] (0.413)	2.55[b] (0.187)
October	2.12[a] (0.182)	2.29[a] (0.229)	1.47[b] (0.214)	1.46[b] (0.293)
November	2.02[ab] (0.176)	2.27[b] (0.275)	1.55[a] (0.221)	1.58[a] (0.335)
December	4.44[a] (0.589)	5.30[b] (0.375)	5.57[b] (0.739)	6.68[c] (0.471)
January	3.83[a] (0.370)	4.42[b] (0.293)	6.11[c] (0.390)	6.99[d] (0.432)
February	4.10[ab] (0.068)	4.51[b] (0.441)	3.92[a] (0.183)	4.03[ab] (0.442)
Average	2.31[a] (1.136)	2.49[b] (1.420)	3.04[c] (1.494)	3.36[d] (1.812)

[abcd] Row means with different superscripts differ significantly ($P<0.05$)

Grassveld had a higher average butyric acid concentration during year 2 compared to year 1. Ranteveld also had higher average butyric acid concentration during year 2 compared to year 1. There were differences between Ranteveld and Grassveld in terms of average butyric acid concentrations for both year 1 and year 2 respectively. Ranteveld had higher average butyric acid concentrations compared to Grassveld.

Figure 40 showed the monthly average butyric acid concentration for the trial period. Large seasonal variation was observed for both Grassveld and Ranteveld. Butyric acid concentrations in Grassveld were higher ($P<0.05$) for December, January and February compared to the other dry season months in Grassveld. Ranteveld followed the same general trend with higher ($P<0.05$) values for April, December, January and February compared to the other months in the Ranteveld.

Ranteveld had higher ($P<0.05$) butyric acid concentrations compared to Grassveld for all of the months except, September, October, November and February.

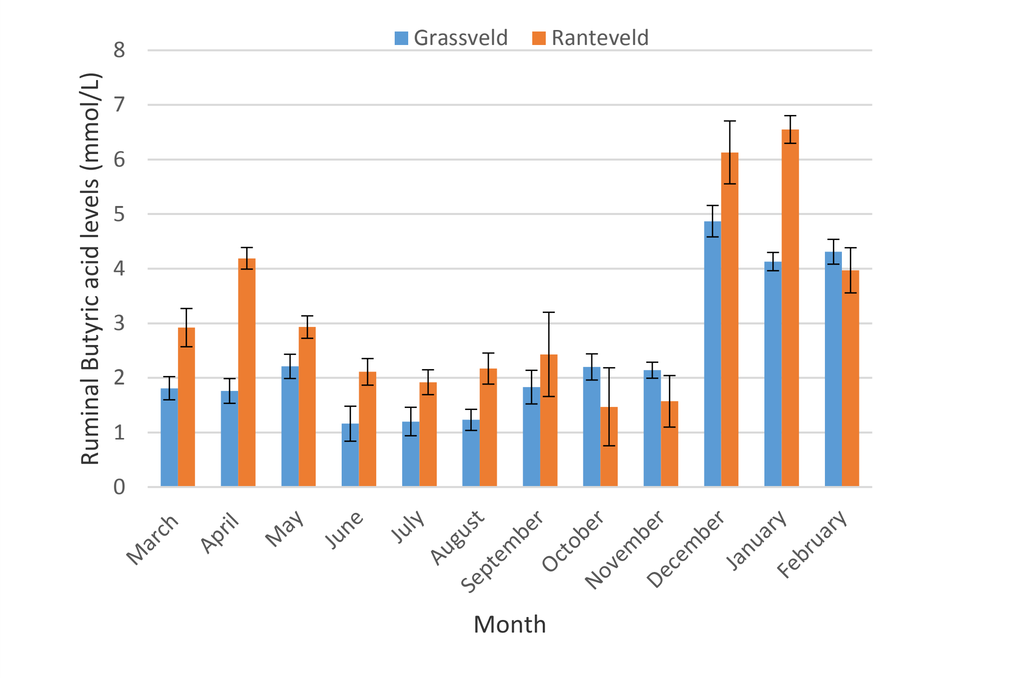

Figure 40 The average butyric acid concentrations for sheep grazing two veld types in the Northern Cape (mmol/L)

The concentration of butyric acid during this trial was very low. The levels are lower compared to trials done by Adams *et al.* (1987), Park *et al.* (1994) and Roodt (2012). The reason for these low levels might lie in the high forage component (Table 14) with low levels of readily fermentable carbohydrates in the diet (Annison *et al.,* 2002).

The acetic acid to propionic acid ratio is shown in Figure 41. The ratio varies during the year. During the beginning of winter the ratio is above 3:1 which may lead to a reduction of microbial protein synthesis (Corbett, 1987). There is a larger annual variation in the Ranteveld, compared to Grassveld. Microbial protein production is directly related to the propionic acid concentration in the rumen (Dove & Milne, 1994; Trevaskis *et al.,* 2001). Under optimal conditions the acetate : propionate ratio should be between 2.2 and 1. Higher acetate : propionate ratios are indicative of high fibre diets with slow fermentation and higher rumen pH. These diets have lower energy production compared to high starch diets with lower acetate : propionate ratios (Van Soest, 1994).

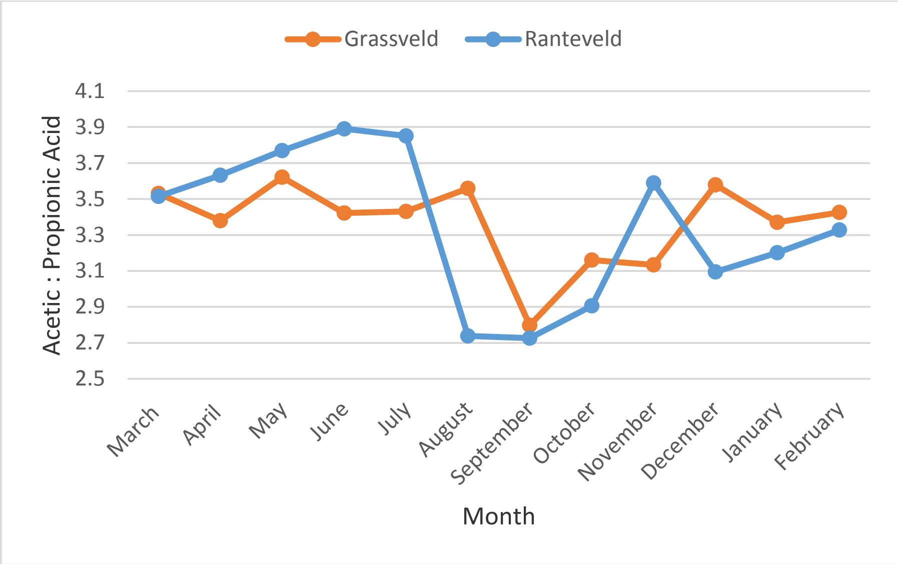

Figure 41 Ruminal fluid acetic acid to propionic acid ratio for two veld types in the Northern Cape, in sheep

4.6. FAECAL INDICATORS

4.6.1. Faecal Crude Protein

The faecal CP was tested as an indicator of the nutritional status of the diet and shown in Figure 42 for Grassveld and Ranteveld.

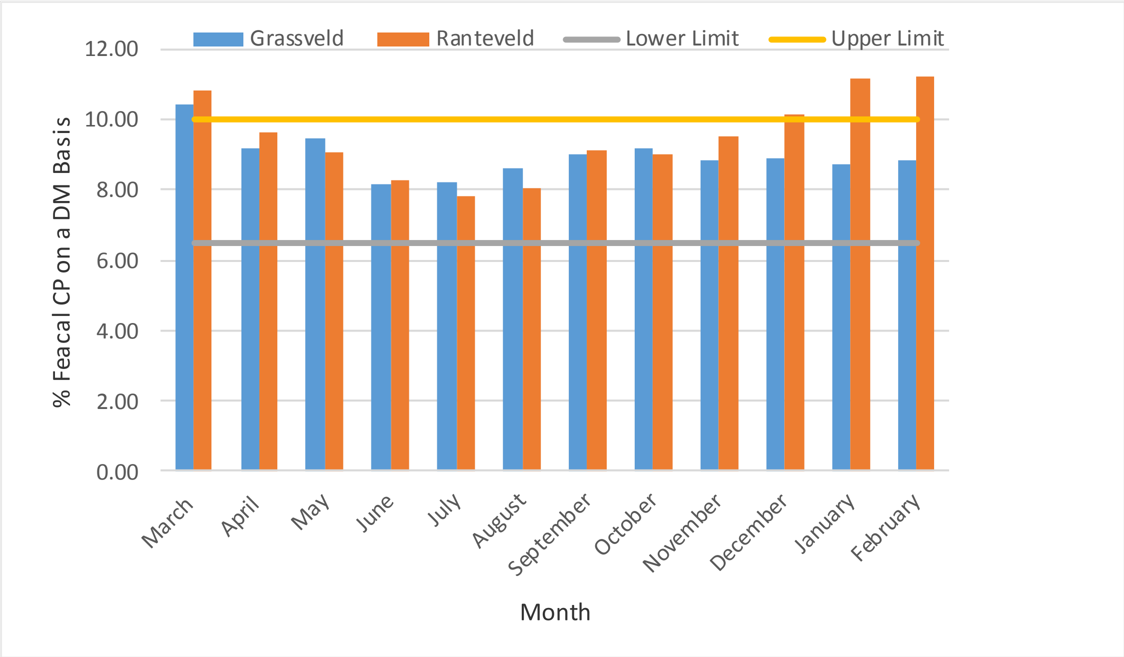

Figure 42 The mean monthly faecal crude protein % on a dry matter basis. A lower limit of 6.5% of faecal crude protein and an upper limit of 10% of faecal crude protein as suggested by Grant (1989) is indicated on the graph.

According to Grant (1989), the faecal CP can be used to indicate when there is a need to supplement protein to the grazing animals. If the values of Grant (1989) was to be used as a guide, the animals should receive a protein supplement for most of the year in Grassveld. For Ranteveld protein supplementation would be restricted to the dry season.

In an attempt to test whether faecal CP could be used as an predictor of the crude protein status of the diet, regressions were determined between the oesophageally collected extrusa protein analysis and the faecal crude protein for the corresponding month. Figure 43 shows the regression for Grassveld and Figure 44 shows the regression for Ranteveld.

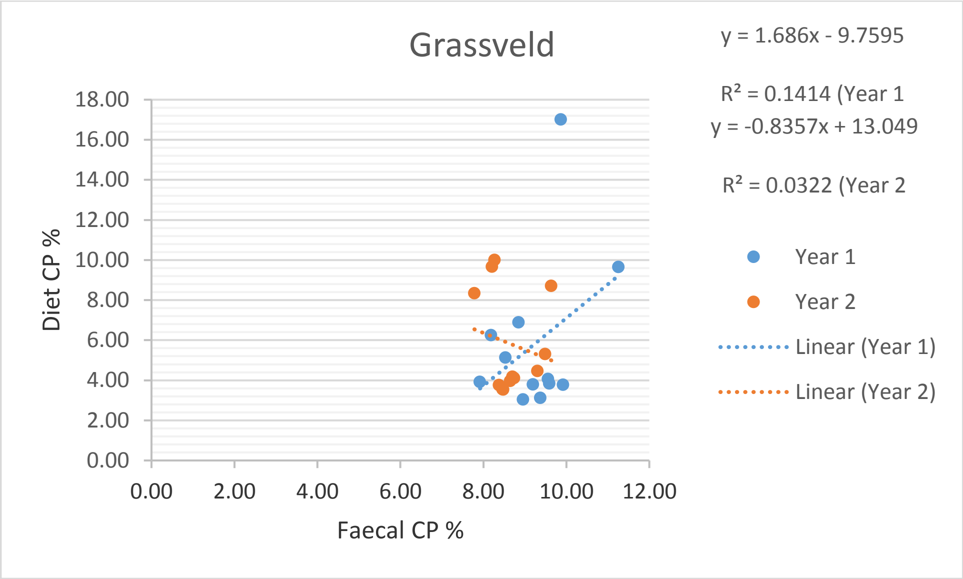

Figure 43 Regression between diet crude protein % and faecal crude protein % for Grassveld. (Year 1 R^2 = 0.1414; Year 2 R^2 = 0.0322)

For Grassveld the R^2 values for both years are not strong enough to show a relationship between the faecal CP % and the diet CP %. The use of such relationships needs to be tested under specific conditions and will need to be formulated for a specific environment under specific management and production conditions.

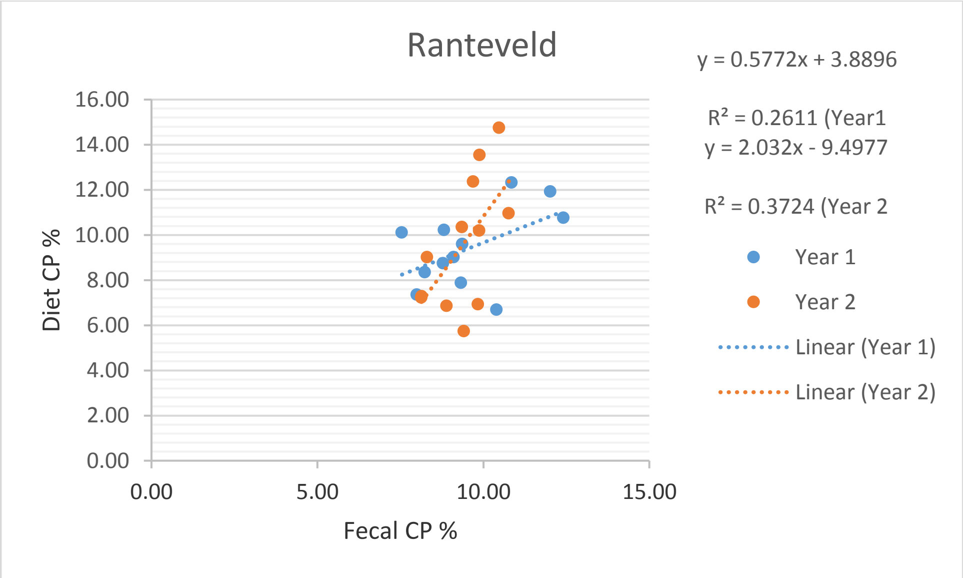

Figure 44 Regression between diet crude protein % and faecal crude protein % for Ranteveld. (Year 1 R^2 = 0.2611; Year 2 R^2 = 0.3724)

A stronger relationship between faecal CP % and diet CP % exists for Ranteveld. The R^2 value however is still too low to suggest that faecal CP can be used as a tool to determine whether crude protein or N should be supplemented. Hobbs (1987) stressed the fact that there are various environmental and dietary effects that vary with space and time, together with inter-animal variability that reduces the effectiveness for the use of faecal-N to make reliable and quantitative predictions of diet quality in grazing herbivores.

4.6.2. Faecal Phosphorus

Grant (1989), suggested the use of faecal P as an indicator of the P status of the diet consumed by cattle. Grant (1989) set a lower limit of 2.2% faecal P to indicate levels at which P supplementation was needed for cattle. An upper limit of 3.5% was set which indicated that no supplementation of phosphorus was needed for cattle according to Grant (1989). Values of between 2.2 and 3.5% were indicated as normal for grazing cattle. Scott *et al.* (1995) showed that the main factor affecting total endogenous phosphorus loss (endogenous phosphorus in faeces and phosphorus in urine) in sheep was the total phosphorus intake in the diet. Other factors affecting the P excretion in faeces include higher requirements for phosphorus by the animal during various physiological stages, including gestation and lactation (Cohen, 1974; Read *et al.,* 1986). The Ca : P ratio should also be considered when taking into account the absorption of Calcium and Phosphorus from the gastrointestinal tract as an imbalance in the ratio will lead to altered absorption patterns of these minerals (NRC, 2007). The average faecal phosphorus concentration for the trial period is shown in Figure 45.

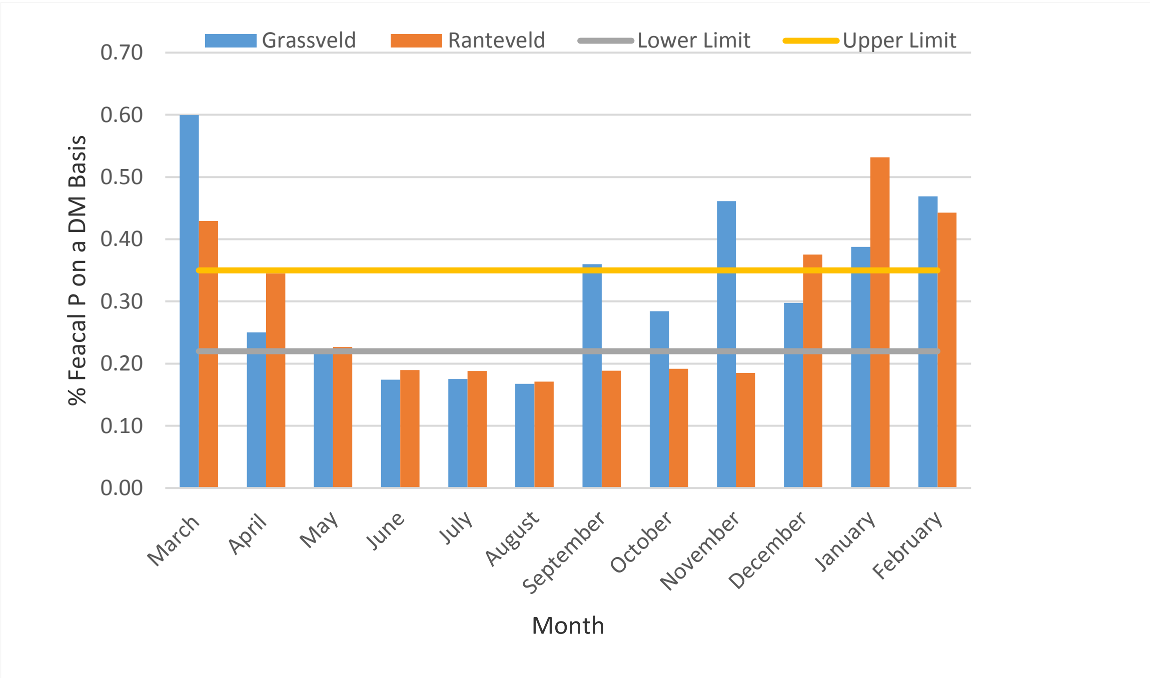

Figure 45 The mean monthly faecal phosphorus % on a dry matter basis. Lower limit of 2.2% and an upper limit of 3.5% as suggested by Grant (1989) is indicated

If the values suggested by Gant (1989) is to be used for this trial it indicates that phosphorus supplementation should be provided during April to November on the Ranteveld. Grassveld showed a shorter period of phosphorus shortages with supplementation needed only for May, June, July and August.

The relationship between faecal P and diet P was tested as Grant (1989), suggested. For Grassveld and shown in Figure 46, however there was a weak relationship between diet P and faecal P. Faecal P will thus not be a good indicator of the P status of the diet consumed by sheep under these conditions.

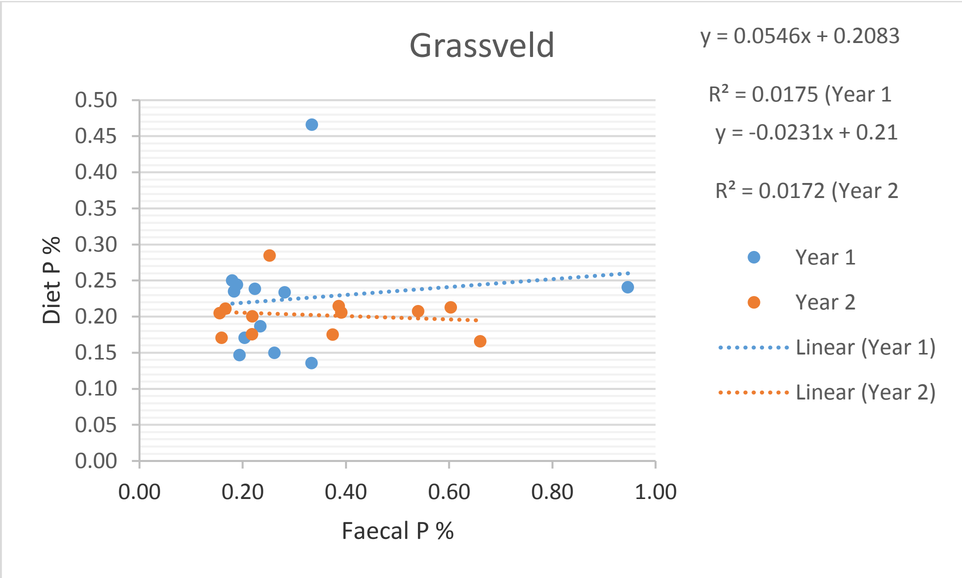

Figure 46 Regression between diet phosphorus % and faecal phosphorus % for Grassveld. (Year 1 R^2 = 0.0175; Year 2 R^2 = 0.0172)

The relationship between faecal P% and diet P% is shown in Figure 47. Ranteveld in year 1 showed a strong relationship between faecal P and diet P concentrations with an R^2 = 0.8635. Year 2 however had an R^2 = 0.1431 which casted doubt on the trustworthiness of using faecal P as an indicator of diet P as consumed by animals under desert range conditions.

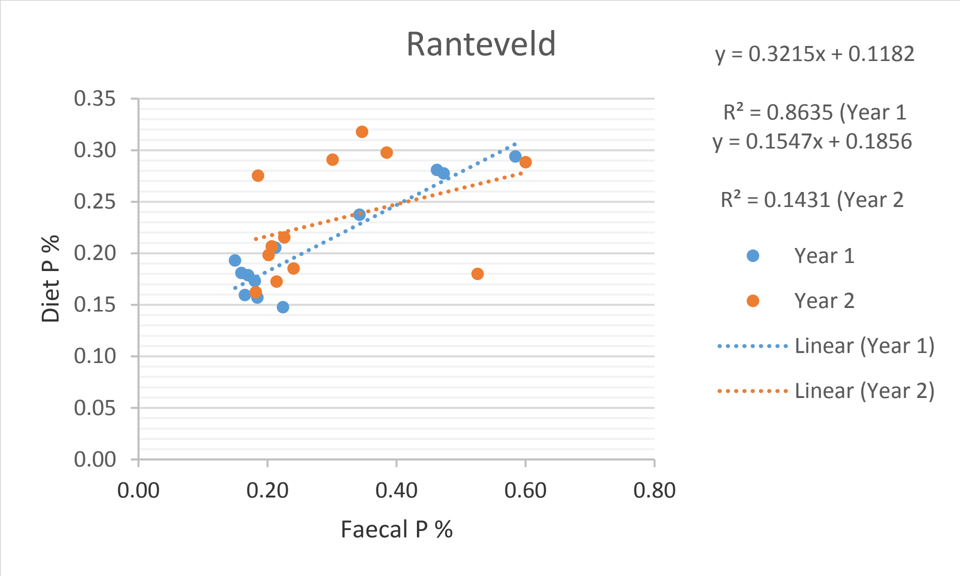

Figure 47 Regression between diet phosphorus % and faecal phosphorus % for Ranteveld. (Year 1 R^2 = 0.8635; Year 2 R^2 = 0.1431)

Hakkila *et al.* (1988), suggested that faecal P be used as an indicator of the diet CP. Subsequently regressions were determined to test the relationship between faecal P and CP. These regressions are shown in Figure 48 and Figure 49.

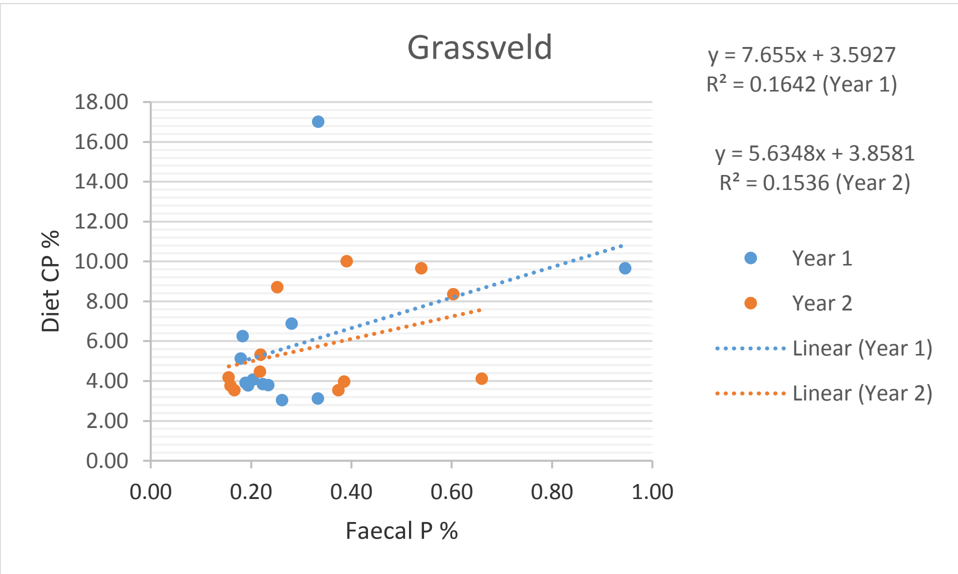

Figure 48 Regression between diet crude protein % and faecal phosphorus % for Grassveld. (Year 1 R^2 = 0.1642; Year 2 R^2 = 0.1536)

For Grassveld the R^2 values for year one and year two respectively are 0.1642 and 0.1536. This indicates that there is a weak relationship between faecal P and diet crude protein under these conditions.

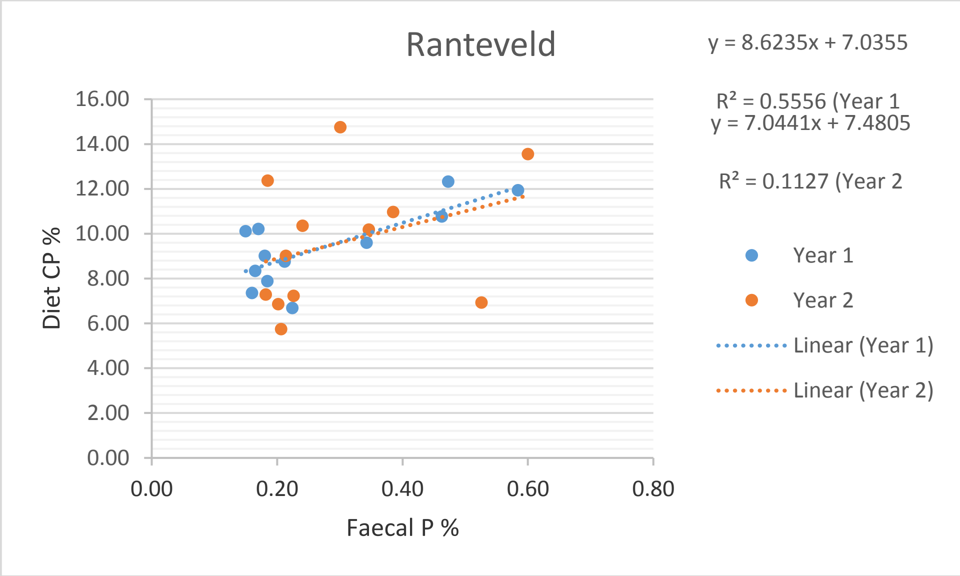

Figure 49 Regression between diet crude protein % and faecal phosphorus % for Ranteveld. (Year 1 R^2 = 0.5556; Year 2 R^2 = 0.1127)

For Ranteveld the R^2 values are higher but there is still a lack of consistency. Year 1 had an R^2 = 0.5556 which sowed some promise for the use of faecal phosphorus as a diet indicator but year 2 had an R^2 = 0.1127. The faecal P would thus not be a sound method to relate to the diet CP on these arid rangelands for sheep.

Chapter 5

General Discussion

5.1. GENERAL DISCUSSION

The purpose of this study was to quantify the nutritive value of two veld types in the Northern Cape and also to identify limitations regarding animal production directly from the natural pasture.

One of the biggest factors affecting livestock production in the arid parts of Southern Africa is the erratic rainfall. Rainfall has the largest influence on forage availability and quality under these extensive farming conditions. Proper veld management in these areas are thus of vital importance to the stock farmer. The farm identified for the trial (Lovedale, Kenhardt district) has been properly managed for over 30 years and was thus able to give good representation of veld in a healthy state.

There were differences regarding quality of veld and the selection of species between the veld types for most of the seasons. The Ranteveld had a higher CP and mineral status for the larger part of the year. The Grassveld on the other hand had very high quality and higher DM production shortly after rains.

Crude protein was identified together with phosphorus to be the first limiting nutrients for Grassveld and Ranteveld. Ranteveld during the dry winter months had a consistently and significantly ($P<0.05$) higher CP when compared to Grassveld. This indicates that protein shortages may not be as severe during winter on the Ranteveld compared to the Grassveld. During the green season Grassveld had high CP content within a few days after good rains. The use of a high crude protein supplement during the winter is advised for both camps. This will lead to improved intake and digestion (Köster *et al.,* 1996; Nolte *et al.*, 2003.) The lower levels of crude protein can be supplemented by means of a protein or production lick. It is advisable for the farmer to try and coincide lambing with the higher rainfall months which would lead to higher protein levels and higher milk production with lower costs from supplementation. For a lambing season to begin in January the farmer needs to breed the ewes in August to September. During this time good management coupled with a protein supplementation program and the use of spare camps, preferably in the Ranteveld, can be used as a means of flush feeding This will help the farmer to achieve higher conception rates with his flock even though this is not the natural breeding season for sheep. The ewes that does not get pregnant during the August/September breeding season can be re-bred during the wet summer months (January to March). This however means that the ewe will lamb during the dry winter months where it will be of benefit to place these lambing ewes on the Ranteveld camps together with a protein supplement.

Phosphorus for the trial area and period was one of the interesting factors that was measured. The common opinion from farmers was that phosphorus was sufficient especially on the mineral rich shrubs that was found in the Ranteveld. The trial pointed out that this was not the case. In fact for some of the months the P concentration in the Grassveld was higher than in the Ranteveld. The P concentration however was almost always below the requirements set by the NRC for a 60 kg mature ewe in mid lactation with milk production of 0,58 kg/day at DMI levels of 2.68% BW (NRC, 2007). This shows that P supplementation could have positive effects. Positive effects to phosphorus supplementation in cattle was shown in studies done in Southern Africa by Read *et al.* (1986), De Waal (1990), and Roodt (2012).

High concentrations of Ca was found on both veld types. The high levels of Ca intake from the veld coupled with high Ca levels in the drinking water will lead to a Ca:P imbalance. High Ca:P ratios may limit the absorption of phosphorus leading to acute phosphorus deficiencies (Ramirez *et al.,* 2001). Phosphorus should be supplemented with a phosphorus source with a low calcium content to avoid an even higher Ca:P ratio. High calcium concentrations leads to lower absorption of magnesium, this can be reflected in lower growth and production rates (McDowell, 2003). High levels of Ca may cause a reduction in the absorption of Se in mature ruminants (Harrison & Conrad, 1984). Zinc bioavailability can be reduced due to the high levels of calcium found in the diet and drinking water competing for absorption sites on the metallothionein which binds and transports zinc (Cousins, 1996).

The mineral balance of the two camps differs widely with Ranteveld, having higher concentrations for Ca, Cu, Mg, Mn, Fe and Zn compared to the Grassveld. Calcium, copper, magnesium and manganese are found in concentrations that are acceptable for most applications for animal production. There is a shortage of Zn in both of the veld types. Supplementation of Zn is highly advised on both of the veld types.

The concentrations of Fe in the grazing was very high. On both veld types the Fe concentration is far higher than required (NRC, 2005). Animals however can adapt to high Fe levels in the diet by reducing the Fe absorption from the gastro intestinal tract (NRC, 2005). These high levels of Fe may also lead to copper deficiency in lambs. (Ivan *et al.,* 1990). It would be advisable to ensure that animals consume adequate amounts of vitamin E to ensure protection against peroxidative damage to lipid membranes due to high concentrations of Fe (NRC, 2007). Mo was found in such low concentrations that it was not possible for the laboratory the measure the presence of Mo.

The metabolisable energy (ME) requirements are more a factor of intake than of the energy density of the ration. Animals can change their daily DM intake depending on the physiological stage of the animal. This is shown by the NRC (2007) tables for nutrient requirements for sheep where the energy concentration in the diet stays the same at 1.91 kcal/kg (8MJ/kg). This value stays the same for a 60kg ewe with a single lamb from gestation through the various stages of lactation. The DM intake however changes through the various stages of maintenance, gestation and lactation. This points to the importance of accurate intake estimations or determinations. Intake estimation for animals on natural pasture is and probably will continue to be one of the most challenging parameters to measure (Romney and Gill, 2000). The ME supplied by the two veld types does however seem to be sufficient for intakes in line with those suggested by NRC (2007). Any supplementation program however with an increase in total ME intake, either by higher intake of natural grazing or by higher nett ME intake due to high ME of a supplement may lead to increased production by the animals. The cost factor though should be considered when working with high intake, energy dense supplements to achieve the desired production.

The addition of energy should be considered for animals especially during times of production in the winter months. The Ranteveld will be able to support animals under production conditions for a longer period of time than Grassveld. Grassveld on the other hand can be of great strategic use for the producer. If the farmer would be able to coincide high production of the animals (e.g. lambing or fattening) with the green summer flush in Grassveld then the producer would receive maximal gains from the animals.

The *in-vitro* organic matter digestibility for the two veld types were very similar with the dry season months showing lower digestibility compared to wet season months. The ability to increase the IVOMD values of forages containing low crude protein concentrations by means of supplementation of nitrogen is well documented and would have a positive effect on animals grazing both veld types during the dry season (Caton, *et al.,* 1988; Köster *et al.,* 1996; Nolte *et al.*, 2003). The IVOMD : NDF ratio suggest lower intakes of dry matter on Grassveld compared to Ranteveld. This is of importance seeing as Grassveld supplies lower concentrations of crude protein and various other minerals when compared to Ranteveld. These lower intakes coupled with lower nutrient concentrations may lead to more severe nutrient shortages of animals on Grassveld grazing. The ADIN levels for this trial is similar to those noted by Roodt (2012) and shows no seasonal trend. The ADIN levels indicate that a further reduction in available nitrogen for rumen fermentation and absorption in the lower gastro intestinal tract can be expected. This will exacerbate the low crude protein concentrations found for the dry season months on both veld types.

In this study three nutritional indicators where evaluated for use in the arid areas of South Africa. Faecal P status was not a consistent indicator for diet CP or diet P status under these conditions. Faecal CP did not show great strength in predicting the CP of the diet. BUN levels on the other hand showed a strong correlation with the diet CP consumed by the animals. The BUN can be used by farmers to evaluate the protein status of animals and the diet. The BUN can also be used to aid the farmers and animal nutritionists to make decisions on the protein supplementation program. A further detailed study is proposed where animals of different breeds, and different experimental sites are used to research stronger regressions for the use on BUN as a nutritional indicator for the CP status of grazing ruminants in the arid parts of South Africa.

5.2 RECOMMENDATIONS

The use, implementation and adherence to a scientific veld management system is of great importance to the livestock farmer in the arid parts of Southern Africa. A veld management system ensures that the veld is kept in a healthy and productive state with maximal returns on the rain that is received annually. This also ensures that the farmer has some supply of rested veld to turn to when there is normally a shortage of veld dry matter. Suggestions for such systems are made by Roux (1966) and Vorster (1999). The farmer is advised to contact a practicing pasture scientist for help in implementing such a system.

The strategic use of camps together with the use of a supplementation program will enable farmers to produce the most mutton per hectare at the lowest cost possible.

It is recommended that the Ranteveld be saved for long periods (at least one growing season) to ensure sufficient storage of reserves in the plants. The Ranteveld camps can be grazed strategically for short periods when the animals have a higher need for high levels of nutrients. These periods include the breeding season and six weeks prior to and after lambing. These essential periods will have the largest effect on the economics of an extensive farming enterprise as these periods determines the amount of offspring that will be produced for the year (Seymour, 1998).

The Grassveld can be utilized by lower producing animals and animals at maintenance. As grass plants store their reserves in their roots the plants can be grazed down relatively short after the growing season has stopped without negatively influencing subsequent production (Van Oudtshoorn, 1991). The Grassveld still has sufficient energy during the winter but the lack of protein and possibly palatability limits intake and digestion. The use of a protein supplement on these pastures will result in increased production due to higher rumen ammonia-N levels, leading to higher NDF digestibility and higher rumen passage rates. (Köster *et al.,* 1996; Nolte *et al.*, 2003; Detmann, 2009). Higher NDF digestibility and higher rumen passage rates will lead to higher dry matter intakes. These higher intakes leads to higher total daily nutrient intake by the animal and is the main driver of production for ruminants (NRC, 2007).

During periods of prolonged droughts and during the latter part of the dry season the use of creep feed for lambs can increase the weight gain of lambs with earlier weaning, and thus less weight loss by the ewe. The earlier weaning also leads to lower total veld intake by the lambs resulting in a saving effect of pasture that will be available to producing animals in the flock.

Recommended supplements for the use in a supplementary feeding program will include the following:

Phosphorus lick (P) – The goal with this supplement is to purely supplement the required minerals without reducing the total pasture intake. This supplement will be given during the periods where the natural grazing supplies sufficient protein and energy and where phosphorus is suspected to be the first limiting nutrient. This supplement will be made from P-sources containing low levels of Ca, and Fe. A mineral premix should be included to supply 100 % of the required Cu, Mg, Mn, Mo and Zn for maintenance of a 60kg ewe

(NRC, 2007). Daily intake off the supplement must be low in order to avoid substitution, in the region of 20g/ewe/day on a DM basis.

Protein lick (N) – This supplement will be given during periods of medium production on low protein veld. This supplement will supply protein to aid in digestion and production. The ideal is for this supplement to have a complementation effect on the grazing, with subsequently higher veld dry mater intakes. This supplement will contain NPN-sources to serve as a cheap and readily available protein source. Natural protein sources may also be included to limit the total NPN intake reducing risk of urea poisoning and to supply degradable protein sources over a longer period of time (Gurthrie & Wagner, 1988; Heldt *et al.,* 1999). The aim is to supply 60% of the required crude protein for a 60kg ewe at maintenance (NRC, 2007). The supplement will also contain a vitamin and mineral premix to supply 60% of the required Cu for maintenance of a 60kg ewe (NRC, 2007). The premix will also contain 100% of the required Mn, Mg, Zn and Mo for maintenance of a 60kg ewe (NRC, 2007). The premix will also contain 100% of the required Vitamin E for maintenance of a 60kg ewe to act as an anti-oxidant to reduce the impact of high dietary Fe concentrations (NRC, 2007). Daily intake will be in the region of 150g/ewe/day based on the work of Freer *et al.* (1988).

Production lick (E) – This supplement will be given during periods of high production on low protein and low energy containing veld. This supplement will contain NPN-sources as well as natural protein sources to supply the required protein to aid in digestion and production. The aim is to supply 60% of the required crude protein for a 60kg ewe at maintenance (NRC, 2007). This supplement will also contain energy sources to lift the total ME intake of the ewe. This supplement will also contain a vitamin and mineral premix to supply 60% of the required Cu for maintenance of a 60kg ewe (NRC, 2007). The premix will also contain 100% of the required Mg, Mn, Zn and Mo for maintenance of a 60kg ewe (NRC, 2007). The premix will also contain 100% of the required Vitamin E for maintenance of a 60kg ewe to act as an anti-oxidant to reduce the impact of high dietary Fe concentrations (NRC, 2007). Intakes will be high at a level of 300g/ewe/day on a DM basis. Substitution of the natural pasture might be found but it will be offset by the higher total nutrient intake from the supplement combined with natural pasture intake.

Table 24 Proposed supplements on a DM basis for use as prescribed in Table 25.

Proposed analysis	Units	Phosphorus Lick	Protein Lick	Production Lick
Phosphosrus (P)	g/kg	100	13.3	6.7
Calcium (Ca)	g/kg	≤100	≤20	≤13
Crude Protein (CP)	g/kg	0-50	333	167
Urea	g/kg	0	66.7	3.33
Meatbolisable Energy (ME)	MJ/kg	0	0	>8
Vitamin E	IU/kg	15500	2066.7	1033.3
Magnesium (Mg)	g/kg	42	9.3	4.7
Zinc (Zn)	mg/kg	2050	453.2	227.8
Copper (Cu)	mg/kg	159	21.2	10.6
Mangense (Mn)	mg/kg	480	107	53.3
Iodine (I)	mg/kg	15	2.0	1.0
Molybdenum (Mo)	mg/kg	25	5.5	2.8
Iron (Fe)	mg/kg	No added Fe	No added Fe	No added Fe
Daily intake per ewe		20g	150g	300g

Table 25 Recommended camp use and supplementation program.

	Animal Production Stage	Grassveld:	Ranteveld:
Wet Season	Breeding	P	P
Early Dry Season	Breeding	N	P
Late Dry Season	Breeding	E	E
Wet Season	Early gestation	P	P
Early Dry Season	Early gestation	P	P
Late Dry Season	Early gestation	N	N
Wet Season	Mid Gestation	P	P
Early Dry Season	Mid Gestation	N	P
Late Dry Season	Mid Gestation	N	N
Wet Season	Late Gestation	P	P
Early Dry Season	Late Gestation	N	N
Late Dry Season	Late Gestation	E	E
Wet Season	Early Lactation	P	P
Early Dry Season	Early Lactation	E	E
Late Dry Season	Early Lactation	E	E
Wet Season	Mid Lactation	P	P
Early Dry Season	Mid Lactation	N	N
Late Dry Season	Mid Lactation	N	N
Wet Season	Late Lactation	P	P
Early Dry Season	Late Lactation	N	P
Late Dry Season	Late Lactation	E	N
Wet Season	Maintenance	P	P
Early Dry Season	Maintenance	P	P
Late Dry Season	Maintenance	N	N

P – Production Lick
N – Nitrogen Lick
E – Production Lick

5.3 CRITICAL EVALUATION

Intake determination under extensive conditions continues to be one of the limiting factors when studying the natural pasture and animal interactions. In this trial it was not possible to obtain intake parameters. The intake models that were used to predict animal performance was devised from the NRC (2005) and models proposed by Cordova *et al.* (1978) and Decruyenaere *et al.* (2009). These models will only give an estimate to what is to be expected under these extensive grazing conditions. Determining intakes however will be costly and a troublesome process because of the extensive nature of the experimental site. In the future the use of controlled release devices for the use in the marker technique would be able to more accurately and easily determine intake of pasture (Decruyenaere *et al.* 2009). Seasonal and temporal changes in this landscape may also affected the intake of animals to such an extent that intake values will be of low importance to researchers in the future.

During this trial cobalt (Co), iodine (I), sulphur (S) and selenium (Se) concentrations were not determined. Sulphur could be an important element in terms of its interactions with copper and molybdenum. High sulphur levels in the forage and water could lead to lower absorption of copper and molybdenum (Spears, 2003).

Further studies should be undertaken to establish the use of BUN levels as a nutritional indicator for the commencement and cessation of protein supplementation programs in the arid parts of South Africa. This method is cost effective and not labour intensive. Certified laboratories are available throughout Southern Africa and turnaround times for results are less than a week. This can give great insight into the nutritional status of animals to both researchers and farmers alike.

Under these extensive conditions farmers are able to attend to flocks only once per week under certain circumstances. It is thus advisable for the farmer and animal nutritionist to use and formulate supplements that are utilised in lesser amounts and that is not affected heavily by weather conditions.

The strategic use of supplements will be the farmer’s most profitable means of improving production under extensive conditions. When using a scientific veld management system together with a supplementation program the farmer will be able to increase lambing % and weaning % as-well as weaning weight. These are the most important factors determining profitability of an extensive sheep farming enterprise.

References

Acocks, J.P.H., 1990. Veld types of South Africa (3rd Ed.). Mem. Bot. Surv. S. Afr. No 28. Government printer, Pretoria.

Adams, D.C., Cochran, R.C. & Currie, P.O., 1987. Forage maturity effects on rumen fermentation, fluid flow and intake in grazing steers. J. Range. Management 40(5), 404-408.

Adegosan A.T., Givens D.I. & Owens E., 2000. Measuring chemical composition and nutritive values in forages. In: t'Mannetje L. & Jones R.M., eds. Field and laboratory methods for grassland and animal production research. Wallingford, UK: CAB International, 263-278.

Allden, W.G., 1962. Rate of herbage intake and grazing time in relation to herbage availability. Waite agricultural research institute. University of Adelaide.

Anke, M., Grun, M., Partscehfeld, M. & Groppel, B., 1978. Molybdenum deficiency in ruminants. Proceedings of the 3rd international symposium of trace element metabolism in man and animals. Germany pp. 230-235.

Anke, M. & Risch, M.A., 1989. Importance of molybdenum in animal and man. Proc. 6th Inter. Trace Suppl. Symp. P 303.

Annison, E.F., Lindsay, D.B. & Nolan, J.V., 2002. Digestion and Metabolism. In: Sheep Nutrition. CABI Publishing. Wallingford. Oxford. UK

AOAC., 2002. Official methods of analysis (17th ed.). Association of Official Analytical Chemists. Inc., Arlington, Virginia, U.S.A.

Agreil C. & Meuret M., 2004. An improved method for quantifying intake rate and ingestive behaviour of ruminants in diverse and variable habitats using direct observation. Small Ruminant Res., 54(1-2), 99-113.

Arnold, G.W., 1975. Herbage intake and grazing behaviour in ewes of four breeds at different physiological stages. Aust. J. Agric. Res. 26:1017-1024.

Arnold, G.W., 1981. Grazing Behavior. In: Grazing Animals. Ed. Morley, F.H.W., Elsevier Scientific Publishing, Amsterdam. p. 79.

Arnold, G.W. & Dudzinski, M.L., 1967. Comparison of faecal nitrogen regression and *in vitro* estimates of diet digestibility for predicting the consumption of herbage by grazing ruminants. J. Agr. Sci. 68:213-219.

Arnold, G.W., McManus, W.R. & Bush, I.G., 1964. Studies in the wool production of grazing sheep. I. Seasonal variation in feed intake, liveweight and wool production. Aust. J. Exp. Agri. Husb. 4:392-403.

Beauchemin, K.A., Yang, W.Z. & Rode, L.M., 2003. Effects of particle size of alfalfa-based dairy cow diets on chewing activity, ruminal fermentation and milk production. J. Dairy Sci. 86:630-643.

Belonje, P.C. & Van den Berg, A., 1983. Estimating phosphorus intake by grazing sheep. S. Afr. J. Anim. Sci. 1983, 13(3) 195-198.

Berry N.R., Scheeder, M., Sutter, F., Kröber, T. & Kreuzer, M., 2000. The accuracy of intake estimation based on the use of alkane controlled-release capsules and faeces grab sampling in cows. Ann. Zootech., 49, 3-13.

Black, J.L. & Kenny, P.A., 1984. Factors affecting diet selection by sheep. II. Height and density of pasture. Aust. J. Agric. Res., 35; 565-578.

Booyse, D.G., Harmse, G. and Boomkera, E.A., 2009. Construction and insertion of oesophageal cannulae for use in domestic ruminants. S. Afr. J. Vet. Assc. 80:270-273.

Boval, M., Coates, D.B., Lecomte, P., Decruyenaere, V. & Archimede, H., 2004. Faecal near infrared reflectance spectroscopy (NIRS) to assess chemical composition, *in vivo* digestibility and intake of tropical grass by Creole cattle. Anim. Feed Sci. Tech. 114:19-29.

Bravo, D., Sauvant, D., Bogaert, C. & Meschy, F., 2003. III. Quantitative aspects of phosphorous excretion in ruminants. Reprod. Nutr. Dev. 43,285-300.

Breen, M.J., & R.A. Hunter. 1976., An improved esophageal fistula plug. J. Aust. Inst. Agric. Sci. 42: 126.

Brendon, R.M. & Short, A.M., 1971. Research note: Oesophageal fistulation of cattle for pasture utilisation studies, post-fistulation care and use of animals and sampling procedures. Agroanimalia 3, 141-144.

Brendon, R.M., Lyle, A.D. & Swart, C.E., 1970. The use of oesophageal fistulated cattle on wet veld in east Griqualand. Proc. S. Afr. Anim. Prod. 9, 163-167.

Broderick, G.A. & Kang, J.H., 1980. Automated simultaneous determination of ammonia-N and total amino acids in ruminal fluid and *in vitro* media. J. Dairy. Sci. 63:64-75.

Burns, J.C., Fisher, D.S., Pond, K.R. & Timothy, D.H., 1992. Diet characteristics, digesta kinetics, and dry matter intake of steers grazing eastern gamagrass. J. Anim. Sci. 70:1251-1261.

Burrit, E.A., Pfister, J.A. & Malecheck, J.C., 1988. Effect of drying method on the nutritive composition of esophageal fistula forage samples: influence of maturity. J. Range Manage. 41(4).

Casey, N.H. & Meyer, J.A., 1996. Interim water quality guidelines for livestock watering. Department of Animal and Wildlife Sciences. University of Pretoria. Water Research Commission, Pretoria, South Africa.

Caton, J., Freeman, A.S. & Galyean, M.L., 1988. Influence of protein supplementation on forage intake, *in situ* forage disappearance, ruminal fermentation and digesta passage rates in steers grazing dormant Blue Grama rangeland. J. Anim. Sci. 66(9) 2262-2271.

Chacon, E.A., Stobbs, T.H. & Dale, M.B., 1978. Influence of sward characteristics on grazing behaviour and growth of Hereford steers grazing tropical grass pastures. Aust. J. Agric. Res. 29: 89-102.

Cilliers,J .W. & Van der Merwe, H.J., 1993.Relationship between chemical components of veld herbage and *in vitro* digestibility and estimated intakes of dry matter and digestible dry matter by sheep and cattle. Anim. Feed Sci. Technol. 43,151.

Coates D.B., Schachenmann P. & Jones R.J., 1987. Reliability of extrusa samples collected from steers fistulated at the oesophagus to estimate the diet of resident animals in grazing experiments. Aust. J. Exp. Agric., 27, 739-745.

Coates, D.B. & Penning, P., 2000. Measuring animal performance. IN: Field and laboratory methods for grassland and animal production research. Eds. t'Mannetjie, L. & Jones, R.M., CABI Publishing, New York, USA. Pp 353-402.

Cohen, R.D.H., 1974. Phosphorus nutrition of beef cattle. 4. The use of faecal and blood phosphorus for the estimation of phosphorus intake. Australian Journal of Experimental Agriculture and Animal Husbandry 14:709-715.

Coleman, S.W., 2005. Predicting forage intake by grazing ruminants. Florida Ruminant Nutrition Symposium. 72-90

Cook, C.W. & Harris, L.E., 1951. A comparison of the lignin ratio technique and the chromogen method of determining digestibility and forage consumption of desert range plants by sheep. J. Anim. Sci. 10:565-573.

Cook, C.W., Taylor, K. & Harris, L.E., 1962. The effect of range condition and intensity of grazing upon daily intake and nutritive value of the diet on desert ranges. J. Range Manage. 15:1-6.

Corbett, J.L., 1987. Energy and protein utilization by grazing animals. In: Temperate Pastures, Australian Wool Corporation/CSIRO, Melbourne, pp. 341-355.

Cordova, F.J., Wallace, J.D. & Pieper, R.D., 1978. Forage intake by grazing livestock: A review. J. Range Manage. 31(6) 430-438.

Cousins, R.B., 1996. Zinc. In: Present knowledge of nutrition. 7th ed., Filer, I.J. & Zieger, E.E., eds. Washington DC: International Life Science Institute.

Cronjé, P.B., 1990. Supplementary feeding of ruminants – a physiological approach. S. Afr. J. Anim. Sci. 20, 110.

De Bruin, T.D., 1995. The nutritional value of bana grass, greengold and pennaris for sheep. MSc (Agric) Dissertation, University of Pretoria.

De Waal, H.O., Engels, E.A.N. & van der Merwe, F.J., 1980. Supplementing sheep with protein and phosphorus on native pasture of the central Orange Free State 1. Diet composition. S. Afr. J. Anim. Sci. 10, 203–208.

De Waal, H.O., Engels, E.A.N., Van der Merwe, F.J. & Biel, L.C., 1981. Supplementing sheep with protein and phosphorus on native pasture of the central Orange Free State 2. Feed intake. S. Afr. J. Anim. Sci. 11, 217–227.

De Waal, H.O., 1990. Review – Animal production from native pasture (veld) in the Free State region - A perspective of the grazing ruminant. S. Afr. J. Anim. Sci. 20, 1-9.

Decruyenaere, V. Buldgen, A. & Stilmant, D., 2009. Factors affecting intake by grazing ruminants and related quantification methods: a review. Biotechnol. Agron. Soc. Environ. 2009 13(4), 559-573.

Delaby L. & Pecatte J.R., 2003. Feed value of associated grasslands of perennial rye grass/white clover pastures utilised with 6-12 weeks of regrowth. (Valeur alimentaire des prairies d'association ray-grass anglais/trèfle blanc utilisées entre 6 et 12 semaines de repousse). In: Actes de 10e Journées autour des Recherches sur les Ruminants, Rencontres Recherches Ruminants, 3-4.12.2003, Paris, France. Paris : INRA Éditions, 389.

Delaby L., Pecatte J.R., Aufrère J. & Baumont R., 2007. Descriptions and forecasting of multi species grasslands. First results. (Description et prévision de la valeur alimentaire de prairies multi-espèces. Premiers résultats.) In: Actes des 14e Journées autour des Recherches sur les Ruminants, Rencontres Recherches Ruminants, 5-6.12.2007, Paris, France. Paris : INRA Éditions, 249.

DelCurto, T., Hess B.W., Huston, J.E. & Olson, K.C., 2000. Optimum supplementation strategies for beef cattle consuming low quality roughages in western United States. J. Anim. Sci. 77, 1-16.

Department of Water affairs and Forestry, 1996. South African water quality guidelines. Vol. 1. Domestic use. Department of Water affairs and Forestry. Pretoria, South Africa.

Detmann, E., Paulino, M.F, Da Silva, J.F.C., Filho, S.V., Zervoudakis, J.T., Da Silva Cabral, L, Cecon, P.B. & Lana, R.P., 2006. Digestibility of acid detergent insoluble nitrogen in cattle grazing signalgrass. R. Bras. Zootec. vol.35 no.4. pp. 1463-1468.

Detmann, E., Paulino, M.F., Hilário C., Mantovani, H.C., Filho, S.V., Sampaio, C.B., de Souza, M.A., Lazzarini, I. & Detmann, K.S.C., 2009. Parameterization of ruminal fibre degradation in low-quality tropical forage using *Michaelis–Menten* kinetics. Livest. Sci. 126 (2009) 136–146.

Dietz, D.R., 1970. Animal production and forage quality. Definitions and components of forage quality. Range and Wildlife Habitat Evaluation – A Research Symposium. May 1970. 1-9.

Donnely, J.R., Davidson, J.L. & Freer, M., 1974. Effect of body condition on intake of food by mature sheep. Aust. J. Agr. Res. 25:813-823.

Dove, H. & Milne, J.A., 1994. Digesta flow and rumen microbial protein production in ewes grazing perennial ryegrass. Aust. J. Agric. Res. 45; 1229-1245.

Du Toit, P.C.V., 1998. A comparison of the diets selected by Merino and Dorper sheep on three ranges types of the Karoo, South Africa. Arch. Zootec. Vol. 47, Núm. 177, p. 21-32.

Dudzinski, M.L. & Arnold, G.W., 1973. Composition of the diets of sheep and cattle grazing together on sown pastures on the southern table lands of New South Wales by principle of component analysis. Aust. J. Agric. Res. 24: 899-912.

Egan, A. R. & Kellaway, R.C., 1971. Evaluation of nitrogen metabolites as indices of nitrogen utilization in sheep given frozen and dry mature herbages. Brit. J. Nutr. 26, 335.

Els, J.F., 2000. Diet selection of four free ranging breeds of small stock I. Chemical composition. Agricola, 11. 33-35.

Engels, E.A.N., 1983. Nutrition research with grazing ruminants. S. Afr. J. Anim. Sci. 13, 292-298.

Engels, E.A.N., Ferreira, B., Swart, J.A. & Niemann, P.J., 1978. Comparative feed intake and digestibility studies with sheep and cattle on roughages. S. Afr. J. Anim. Sci. 8, 149.

Fairweather-Tait, S.J. & Wright, A.J.A., 1984. The influence of previous iron intake on the estimation of bioavailability of Fe from a test meal given to rats. Br. J. Nutr. 51-185-191.

Faure, A.S., Minnaar, G.J. & Burger, F.J.L., 1982. The nutritive value of natural pasture in the Gordonia district. S. Afr. J. Anim. Sci. 13(2).

Fels, H.E., Moir, R.J. & Rossiter., 1959. Excreta collection apparatus for wethers. J. Anim. Sci. 18:935-937.

Ferreira L.M.M., Olivan, M., Rodrigues, M.A.M., Osoro, K., Dove, H. & Dias-da-Silva, A., 2004. Estimation of feed intake by cattle using controlled-release capsules containing n-alkanes or chromium sesquioxide. J. Agric. Sci., 142,225-234.

Fisher, D.S., 2002. A review of a few key factors regulating voluntary feed intake in ruminants. Crop Sci. 42: 1651-1655.

Freer, M. & Jones, D.B., 1984. Feeding value of subterranean clover, lucerne, phalaris and Wimmera ryegrass for lambs. Aust. J. Exp. Agric. Anim. Husb. 24:156-164.

Freer, M., Dove, H., Axelsen, A. & Donnely, J.R., 1988. Responses to supplements by weaned lambs grazing mature pasture or eating hay cut from the same pasture. J. Agric. Sci. Camb. 110, 661-667.

Giron, H.C., 1997. Atomic Absorption Newsletter 12.28. Perkin Elmer Atomic Spectrophotometer.

Goering, H. K. & Van Soest, P. J., 1988. Forage Fibre Analysis (Apparatus, reagents, procedures and some applications). Agricultural Handbook No. 379. A.R.S., U.S. Dept of Agric. ADSRI Jan 1988.

Graham, N.M.C., 1964. Energy costs of feeding activities and energy expenditure of grazing sheep. Aust. J. Agric. Res. 15(6) 969 – 973.

Grant, C.C., 1989. Development of a system classifying and monitoring the availability of minerals to cattle in the ranching areas of S.W.A./Namibia. DVsc. Thesis. University of Pretoria, South Africa.

Grant, C.C., Biggs, H.C. & Meissner, H.H., 1996. Demarcation of potentially mineral-deficient areas in central and northern Namibia by means of natural classification systems. Onderstepoort J. Vet. Res. 63:109-120.

Guthrie, M.J. & Wagner, D.G., 1988. Influence of protein or grain supplementation and increasing levels of soybean meal on intake, utilization and passage rate of prairie hay in beef steers and heifers. J. Anim. Sci. 66: 1529-1537.

Hakkika, M., Holencheck, J.L., Wallace, J.D., Anderson, D.M. & Cardenas, M., 1988. Fecal indicators of cattle protein status on desert grassland range. Nutrition Reports International, Vol. 37, No. 1.

Hammond, A.C., 1997. Update on BUN and MUN as a guide for protein supplementation in cattle. IN: Proc. 8th annual Florida Ruminant Symp. Univ. of Florida, Gainesville. p. 45.

Hammond, A.C., Kunkle, W.E., Bates, D.B. & Sollenberger, L.E., 1993. Use of blood urea nitrogen concentration to predict response to protein or energy supplementation in grazing cattle. In: Proc. of the XVII International Grassland Congress, pp. 1989-1991. Rockhampton, Australia.

Hardy, M.B., Meissner, H.H. & O' Reagain, P.J., 1997. Forage intake and free-ranging ruminants: A tropical perspective. Proceedings of the 1997 International Grasslands Conference, Session 2- Animal intake and Grazing Systems. (45-52)

Hardy, M.B. & Mentis, M.T., 1986. Grazing dynamics in sour Grassveld. S. A. J. Sci: 82 566-572.

Harmoney, K.R., Moore, K.J., George, J.R., Brummer, E.C. & Russel, J.R., 1996. Determination of pasture biomass using four indirect methods. American J. Agr. Vol. 89 No. 4, p. 665-672.

Harniss, R. O., Price, D.A. & Tomlin, D.C., 1975. Number of fistula samples needed for determination of sheep diet on sagebrush-grass range. J. Range Manage. 28:417.

Harrison, J. H. & Conrad, H. R., 1984. Effect of dietary calcium on selenium absorption by the nonlactating dairy cow. *J. Dairy Sci.* 67: 1860–1864.

Harrison, T.H., Van Ryssen, J.B.J. & Barrowman P.R., 1987. The influence of breed and dietary molybdenum on the concentration of copper in tissues of sheep. S. Afr. J. Anim. Sci. 17(2).

Hart, R.H., 1983. Correcting for salivary contamination of oesophageal fistula samples. J. Range Manage. 36. 119-120.

Heldt, J.S., Cochran, R.C., Manthis, C.P., Woods, B.C., Olson, K.C., Titgemeyer, E.C., Nagaraja, T.G., Vanzant, E.S. & Johnson, D.E., 1999. Effects of level and source of carbohydrate and level of degradable intake protein on intake and digestion of low-quality tallgrass-prairie hay by beef steers. J. Anim. Sci. Vol. 77 No. 10, p. 2846-2854.

Hitz, A.C., Russell, J.R., Maxwell, D.R. & Secor, L.J., 1997. Efficacy of grazing stockpiled perennial forages for winter maintenance of beef cows. Iowa State University. Beef Res. Report. Paper 28.

Hobbs, N.T., 1987. Fecal indices to dietary quality: A critique. J. Wildl. Manage. 51;317-320.

Holenchek, J.L., Vavra, M. & Pieper, R.D., 1982. Methods for determining the nutritive quality of range ruminant diets: A Review. J. Anim. Sci. 54(2), 363-376.

Hoover, W.H., 1986. Chemical factors involved in ruminal fibre digestion. J. Dairy Sci. 69, 2755–2766.

Huntington, G.B. & Arcibeque, S.L., 2000. Practical aspects of urea and ammonia-N metabolism in ruminants. J. Anim. Sci. 77:1-11.

Huntington, G.B., Poore, M., Hopkins, B. & Spears, J., 2001. Effect of ruminal protein degradability on growth and N metabolism in growing beef steers. J. Anim. Sci. 79:533-541.

Ivan, M., Hidiroglou, M., Al-Ismaily, S.L., Al-Sumry, H.S. & Harper, R.B., 1990. Copper deficiency and posterior paralysis (Shalal) in small ruminants in the Sultanate of Oman. Trop. Anim. Hlth. Prod. 22:217-225.

Jarrige, R., Demarquilly, C., Dulphy, J.P., Hoden, A., Robelin, J., Beranger, C., Geay, Y., Journet, M., Malterre, C., Micol, D. & Petit, M., 1986. The INRA system for predicting the voluntary intake of forage-based diet in ruminants: a review. J. Anim. Sci., 63, 1737-1758.

Jones R.J. & Lascano C.E., 1992. Oesophageal fistulated cattle can give unreliable estimates of the proportion of legume in the diets of resident animals grazing tropical pastures. Grass Forage Sci., 47, 128-132.

Karn, J.F., 1995. Phosphorus supplementation of replacement heifers in the Northern great plains. J. Range. Manage. 48; 493-497.

Köster, H.H., Cochran, R.C., Titgemeyer, E.C., Vanzant, E.S., Abdelgadir, I. & St.-Jean, G., 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, Tallgrass-Prairie forage by beef cows. J. Anim. Sci. 74:2473-2481.

Langlands, J.P., 1968. The feed intake of grazing sheep differing in age, breed, previous nutrition and live-weight. J. Agr. Sci. 71:167-172.

Langlands, J.P., 1974. Studies on the nutritive value of the diet selected by grazing sheep. VII. A note on hand-plucking as a technique for estimating dietary composition. Anim. Prod. 19, 249.

Langlands, J.P. & Bowles, J.E., 1974. Herbage intake and production of Merino sheep grazing native and improved pastures at different stocking rates. Aust. J. Exp. Agr. Anim. Husb. 14:307-315.

Launchbaugh, K.L., Provenza, F.D., & Pfister, J.A., 2001. Herbivore response to anti-quality factors in forages. J. Range Manage. 54: 431–440.

Leibholz, J., 1970. The effect of starvation and low nitrogen intakes on the concentration of free amino acids in the blood plasma and on the nitrogen metabolism in sheep. Austr. J. Agr. Res. 23, 723.

Leigh, J.H. & Mulham, W.E., 1966. Selection of diet by sheep grazing semi-arid pastures on the Riverine plain. 1. A bladder saltbush (*Atriplex Visicaria*) – cotton bush (*Kochia aphylla*) community. Aust. J. Exp. Agric. Husb. 6:460-467.

Leng, R.A., 1990. Factors affecting the utilization of poor quality roughages by ruminants, particularly under tropical conditions. National research review 3, 27.

Leng, R.A., 1993. Quantitative ruminant nutrition – A green science. Aust. J. Agic. Res. 44: 363-80.

Lewis, D., 1957. Blood-urea concentration in relation to protein utilization in the ruminant. J. Agr. Sci. 48:438.

Lippke H., 2002. Estimation of forage intake by ruminants on pasture. Crop Sci., **42**(3), 869-872.

Little, D.A., 1975. Studies on cattle with oesophageal fistulae. Comparison of concentrations of mineral nutrients in feeds and associated boluses. Aust. J. Exp. Agric. Ani. Husb. 15, 437-439.

Louvandini, H. & Vitti, D.M.S.S., 1996. Phosphorus metabolism and estimation of phosphorus requirements for sheep. Sci. Agric. Vol. 53.

Lyons, R. K., & Stuth, J.W., 1992. Fecal NIRS equations for predicting diet quality of free-ranging cattle. J. Range Manage. 45:238-244.

Marshall, B., Torrell, D.T. & Brendon, R.M., 1967. Comparison of tropical forages of known composition with samples of these forages collected by oesophageal fistulated animals. J. Range. Manage. 20, 310-313.

Masters, D.G., 1996. Mineral deficiency problems in grazing sheep- an overview. IN: Masters, D.G. & White, C.L. (eds.) Detection and treatments of mineral nutrition problems in grazing sheep. Australian centre for international agricultural research,

Mayland, H.F. & Lesperance, A.L., 1977. Mineral composition of rumen fistula samples compared to diet. J. Range Manage. 30(5)

McDowell, L.R., 2003. Minerals in Animal and Human Nutrition. 2nd edition. Elsevier, Amsterdam, Netherlands.

McCosker T. & Winks, L., 1994. Phosphorus nutrition of beef cattle in northern Australia. Department of Primary Industries: Brisbane, Queensland.

McKay, A.D., Frandsen, P.E., Odero, J.C., Sondergaard, M. & Nganga, S.P., 1969. Chemical composition of herbage from Themeda grassland in Kenya before and after collection from oesophageal fistulated steers. East African Agric. For. J. 35, 190-196.

McManus, W.R., Arnold, G.W. & Hamilton, F.J., 1962. Improved techniques in esophageal fistulation of sheep. Aust. Vet. J. 38:275.

Meissner, H.H., 1994. Animal-related information required and a more comprehensive approach to improve estimates of carrying capacity. In: Proceedings of a Symposium on the Science of Free Ranging Ruminants. Fort Hare, October, 1994.

Meissner, H.H., Köster, H.H., Nieuwoudt, S.H. & Coertze, R.J., 1991. Effect of energy supplementation on intake and digestion of early and mid-season ryegrass and Panicum/Smuts finger hay, and on *in sacco* disappearance of various forages pecies S..Afr. J. Anim.Sci.21,33.

Meissner, H.H. & Paulsmeier, D.V., 1995. Plant compositional constituents affecting between plant- and animal species prediction of forage intake. J. Anim. Sci. 73, 2447-2457.

Mertens, D.R., 1987. Predicting intake and digestibility using mathematical models of ruminal function. J. Anim. Sci. 64:1548-1558.

Minson, D.J., 1990a. Forage in ruminant nutrition. Academic Press, New York, USA.

Minson, D.J., 1990b. The chemical composition and nutritive value of tropical grasses. IN Tropical grasses by Skerman, P.J. & Riveros, F. FAO. Rome. Pp 163.

Moore, J.E., 1994. Forage quality indices: development and application. p. 967-998. *In* G.C. Fahey, Jr. et al. (ed.) Forage quality, evaluation, and utilization. ASA, CSSA, and SSSA. Madison, WI.

Moore, J.E., Brant, M.H, Kunkle, W.E. & Hopkins, D.I. 1999. Effects of supplementation on voluntary forage intake, diet digestibility, and animal performance. J. Anim. Sci. (Suppl. 2):122-135.

Moore, J.E., & Coleman, S.W. 2001. Forage intake, digestibility, NDF and adf: How well are they related? Proceedings of the American Forage and Grassland Council. 10:238-242.

Mucina, L., Rutherford, M.C. & Powrie, L.W., 2007. Vegetation map of South Africa, Lesotho and Swaziland. South African National Biodiversity Institute, Pretoria. ISBN 978-1-919976-42-6

NDA., 2013. Newsletter: National Livestock Statistics. Estimated Livestock Numbers in the RSA (August 2012 and May 2013). Department of Agriculture, Forestry and Fisheries. Directorate: Statistics and Economical Analysis. Pretoria. South Africa.

Nelson, B.D., Montgomery, C.R., Schilling, P.E. & Mason, L., 1975. Effects of fermentation time on *in vivo* / *in vitro* relationships. J. Dairy Sci. 59:270-277.

Nolan, J. V., Cocimano, M.R. & Leng, R.A., 1970. Prediction of parameters of urea metabolism in sheep from the concentration of urea in plasma. Proc. Australian. Soc. Anim. Prod. 8, 22.

Nolte, J.E., Ferreira, V.A. & Köster, H.H., 2003. Effect of different rumen degradable protein levels on the utilization of wheat straw by Döhne Merino wethers. Anim. Sci. 76, 319-326.

NRC., 1975. Nutrient requirements of domestic animals. 5. Nutrient requirements of sheep. The National Academic Press, Washington, D.C.

NRC., 1987. Predicting feed intake of food-producing animals. The National Academic Press, Washington, D.C.

NRC., 2005. Mineral Tolerance of Animals, 2nd rev. ed. The National Academic Press, Washington, D.C.

NRC., 2007. National Research Council. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids. 7th revised edition. National Academy press, Washington, DC.

Nunez- Hernandez, G., Holencheck, J.L, Artthun, D., Tembo, A. & Wall, J.D., 1992. Evaluation of fecal indicators for assessing energy and nitrogen status of cattle and goats. J. Range Mange. 45:143-147.

Olson, K.C. & Malechek, J.C., 1984. Technical notes: A temporary esophageal cannula that prevents fistula contraction during extrusa collections. J. Range Manage. 40, 282-283.

O'Reagain P.J. & Owen-Smith, R.N., 1996. Effect of species composition and sward structure on dietary quality in cattle and sheep grazing South African sourveld. J. Agric. Sci. (Camb.), 127, 261-270.

Palmer, T. & Ainslie, A., 2002. Country Pasture/Forage resource profiles South Africa. Part 2. Agricultural Research Council. Hatfield. Pretoria. RSA.

Papachristou, T.G. & Nastis, A.S., 1994. Changes in chemical composition and in vitro digestibility of oesophageal fistula and hand plucked forage samples due to drying method and stage of maturity J. Anim. Feed Sci.46:87–95.

Park, K.K., Krysl, L.J., McCracken, B.A., Judkins, M.B. & Holcombe, D.W., 1994. Steers grazing intermediate wheatgrass at various stages of maturity: Effects on nutrient quality, forage intake, digesta kinetics, ruminal fermentation, and serum hormones and metabolites. J. Anim. Sci. 72, 478-486.

Pasha T.N., Prigge E.C., Russell R.W. & Bryan W.B., 1994. Influence of moisture content of forage diets on intake and digestion by sheep. J. Anim. Sci., 72(9), 2455-2463.

Peare, G.R. & Vercoe, J.E., 1961. The estimation of intake of grazing sheep. II. Application of faecal nitrogen regression to a group of grazing sheep. J. Agr. Sci. 59:349-353.

Peel, M. C., Finlayson, B. L. & McMahon, T. A., 2007. Updated world map of the Köppen-Geiger climate classification. Hydrol. Earth Syst. Sci. 11, 1633-1644.

Penning, P.D., Parsons, A.J., Orr, R.T. & Treacher, T.T., 1991. Intake and behaviour responses by sheep to changes in sward characteristics under continuous stocking. Grass For. Sci. 46, 15-28.

Perdok, H.B., 1987. Ammoniated rice straw as a feed for growing cattle. PhD Thesis, University of New England, Armidale, Australia.

Peripolli, V., Prates, E.R., Barcellos, J.O.J. & Neto, J.B., 2011. Fecal nitrogen to estimate the intake and digestibility in grazing ruminants. Anim. Feed Sci. Techn. 163, 2-4(170-176).

Pietersen, L.M., Meissner, H.H. & Pietersen, E .W., 1993. Food selection and intake by male impalas in the Timbavati area. S.Afr. J. Wildl. Res. 23, 6

Pinchak, W.E., Greene, L.W., & Hunt, L.J., 1990. Biases in relative estimates of dietary mineral status from oesophageal extrusa. J. Range Manage. 43, 136-138.

Poppi, D.P., 1996. Predictions of food intake in ruminants from analyses of food composition. Aust. J. Agric. Res. 47:489-504.

Pratchett, D., Capper, B.G., Light, D.E., Miller, M.D., Rutherford, A.S., Rennie, T.W., Buck, N.G., & Trail, J.C., 1977. Factors limiting live weight gain of beef cattle in Botswana. J. Range Manage. 30, 442-445.

Preston, R. L., Schnakenberg, D.D. & Pfander, W.H., 1965. Protein utilization in ruminants. I. Blood urea nitrogen as affected by protein intake. J. Nutr. 86, 281.

Preston, R.L., Byers, F., & Stevens, K.R., 1978. Estrogenic activity and groeth stimulation in steers fed varying protein levels. J. Anim. Sci. 46:541-546.

Provenza, F. D. & Balph, D.F., 1987. Diet learning by domestic ruminants: Theory, evidence and practical implications. Applied animal behaviour science, 18(211-232).

Provenza, F.D., 1995. Postingestive feedback as an elementary determinant of food preference and intake by ruminants. J. Range Manage. 48, 2-17.

Raats, J.G., Webber, L., Tainton, N.M. & Pepe, D., 1996. An evaluation of the equipment for the oesophageal valve technique. Small Rum. Res. 21, 213-216.

Ramirez, R.Q., Haenlein, G.F.W. & Nunez Gonzalez, M.A., 2001. Seasonal variation of macro and trace mineral contents in 14 browse species that grow in north-eastern Mexico. Small Rum. Res. 39;153-159.

Read, M.V.P., Engels, E.A.N. & Smith, W.A., 1986a. Phosphorus and the grazing ruminant. 1. The effects of supplementary P on sheep at Armoedsvlakte. S. Afr. J. Anim. Sci. 16, 1-6.

Read, M.V.P., Engels, E.A.N. & Smith, W.A., 1986b. Phosphorus and the grazing ruminant. 2. The effects of supplementary P on cattle at Glen and Armoedsvlakte. S. Afr. J. Anim. Sci. 16, 7.

Rice, R.W., Cundy, D.R. & Weyerts, P.R., 1971. Botanical and chemical composition of esophageal and rumen fistula samples of sheep. J. Range Manage. 24(2), 121-124.

Robinson, J.J., 1990. Nutrition over the winter period – the breeding female. IN: Slade, C.F.R. & Lawrence, T.L.J. New developments in sheep production. Occasional publication No. 14, British Society of Animal Production. Edinburgh, pp55-69.

Robinson, P.H., Givens, D.I. & Getachew, G., 2004. Evaluation of NRC, UC Davis and ADAS approaches to estimate the metabolizable energy values of feeds at maintenance energy intake from equations utilizing chemical assays and in vitro determinations. Anim. Feed. Sci. Technol. 114. 75-90.

Romney, D.L. & Gill, M., 2000. Intake of forages. In: Forage evaluation in ruminant nutrition. Eds. Givens, D.I., Owen, E., Axford, R.F.E. & Omed, H.M. CAB International. Wallingford. UK. Pp43-62.

Roodt, W., 2012. Nutritional status and performance of lick supplemented beef cattle in tree and shrub savannah of Namibia. Dissertation for M.Sc. (Agric.) University of Pretoria.

Rook A.J., Harvey, A., Parsons, A.J., Orr, R.J. & Rutter, S.M., 2004. Bite dimensions and grazing movements by sheep and cattle grazing homogeneous perennial ryegrass swards. Appl. Anim. Behav. Sci., 88, 227-242.

Roux. P.W., 1966. Beginsels van veldbeheer in die Karoo en aangrensende droë soetgrasveldstreke. In: Die kleinveebedryf in Suid Afrika. Ed. Hugo, W.J., Government Printer Pretoria.

Russell, J.B., 2002. Rumen microbiology and its role in ruminant nutrition. Ithaca, James B. Russell

Samuels, M.L., 1989. Statistics for the life sciences. Collier Macmillan Publishers, London.

Satter, L.D. & Roffler, R.E., 1977. Influence of nitrogen and carbohydrate inputs on rumen fermentation IN: Recent Advances in Animal Nutrition. Eds. Haresign, W. & Lewis, D.,London, Butterworths. Pp25-49.

Schneider, B.H., & Flatt, W.P., 1975. Pasture consumption and digestibility. The evaluation of feeds through digestibility experiments. The University of Georgia Press. Athens GA.

Scott, D. Rajaratne, A.A.J. & Buchan, W., 1995. Factors affecting faecal endogenous phosphorus loss in the sheep. J. Agric. Sci. 124; 144-151.

Seymour, M., 1998. Farming Ahead, May 1998, No. 77, 77-78

Sharrif, M.A., Boila, J. & Wittenberg, K.M., 1990. Effect of dietary molybdenum on rumen dry matter disappearance in cattle. Can. J. Anim. Sci. 70:319-323.

Simpson, S.J., 2000. Nitrogen utilization and performance in ruminants fed oscillating dietary protein levels. M.Sc. thesis. Virginia Polytechnic Institute and State University.

Singh, V.K., Pattanaik, A.K., Goswami, T.K. & Sharma, K., 2013. Effect of varying the energy density of protein-adequate diets on nutrient metabolism, clinical chemistry, immune response and growth of Muzaffarnagari lambs**.** Asian-Aust. J. Anim. Sci. 26; 1089-1101.

Slyter, L.L., Satter, L.D. & Dinius, D.A., 1979. Effect of ruminal ammonia-N concentration on nitrogen utilization by steers. J. Anim. Sci. 48:906-912.

Soder, J.K., Gregorini, P., Scaglia, G. & Rook, A.J., 2009. Dietary selection by domestic grazing ruminants in temperate pastures: Current state of knowledge, methodologies and future direction. Range. Ecol. Manage. 62(5):389-398.

Spears, J.W., 2003. Trace mineral bioavailability in ruminants. J. Nutr. 133:1506-1059.

Spiekers, H., Brintrup, R, Balmelli, M. & Pfeffer, E., 1993. Influence of dry matter intake on faecal phosphorus losses in dairy cows fed rations low in phosphorus. J. Anim. Physiol. Nutr., 69: 37–43

Squires, V.R., 1980. Chemical and botanical composition of the diets of oesophageally fistulated sheep, cattle and goats in a semi-arid *Eucalyptus populnea* woodland community. The Rangeland Journal. 2(1): 94-103.

Statistical Analysis Systems., 2015. SAS User's Guide: Sttistics Version 9.3 SAS Institute Inc. Cary, NC, USA.

Stevens, D.R., Burns, J.C., Fisher, D.S. & Eisemann, J.H., 2004. The influence of high-nitrogen forages on the voluntary feed intake of sheep. J. Anim. Sci. 82:1536–1542.

Thomas, P.C. & Rook, J.A.F., 1981. Manipulation of Rumen Fermentation IN: Recent developments in ruminant nutrition. Eds. Haresight, W. & Cole, D.J.A., Butterworths, London.

Tilley, J.M.A. & Terry, R.A., 1963. A two stage technique for the *in vitro* digestion of forage crops. J. Britt. Grassld Soc. 18,104.

Topps, J.H. & Elliot, R.C., 1964. Volatile fatty acids in the rumen of African sheep given a variety of low-protein diets. J. Anim. Prod. Vol. 6.pp 91-96.

Torrel, D.T., Bredon, R.M. & Marshall, B., 1967. Variation of oesophageal fistula samples between animals and days on tropical grasslands. J. Range Manage. 20, 314-316.

Torrel, D. T., Hume, I.D. & Weir, W.C., 1974. Factors affecting blood urea nitrogen and its use as an index of the nutritional status of sheep. J. Anim. Sci. 39, 435-440.

Trevaskis, L.M., Fulkerson, W.J. & Gooden, J.M. 2001. Provision of certain carbohydrate-based supplements to pasture-fed sheep, as well as time of harvesting of the pasture, influences pH, ammonia concentration and microbial synthesis in the rumen. Aust. J. Exp. Agric. 41; 21-27.

Undersander, D., Albert, B., Cosgrove, D., Johnson, D. & Peterson, P., 2002. Pastures for profit: A guide to rotational grazing. Cooperative extension publishing. University of Wisconsin.

Valencia, E., Williams, M.J., Chase, C.C., Sollenberger, L.E., Hammond, A.C., Kalmbacher, R.S. & Kunkle, W.E., 2001. Pasture management effects on the diet composition and cattle performance on continuously stocked rhizome peanut-mixed grass swards. J. Anim. Sci. 79:2456-2464.

Van Dyne, G.M. & Heady, H.F., 1965. Dietary chemical composition of cattle and sheep grazing in common on a dry annual range. J. Range. Manage. 18, 78-86.

Van Dyne, G.M. & Torrel, D.T., 1964. Development and use of the esophageal fistula: a review. J. Range Manage. 17, 7-19.

Van Dyne, G.M., & Meyer, J.H., 1964. Forage intake by cattle and sheep on dry annual range J. Anim. Sci. 23:1108-1115.

Van Niekerk, B.D.H., 1996. Supplementation and minimal intervention – Limiting nutrients in supplementary feeding. Bull. Grassld Soc. Sth. Afr. 7, 51-56.

Van Oudtshoorn, F.P., 1991. Gids tot grasse van Suid Afrika. Briza Publikasies, Pretoria, 116-117.

Van Ryssen, J.B.J., 1979. The influence of molybdenum and sulphur on sheep receiving high levels of copper and broiler litter in their rations. S. Afr. J. Anim. Sci. 9,21-25.

Van Schalkwyk, L.P., 1978. Veldevaluasie en voerinname studies met beeste op natuurlike weiding. PhD. Thesis. University of the Free State, South Africa.

Van Soest, P.J., 1994. Nutritional ecology of the ruminant, 2nd ed. Cornell University Press, Ithaca Ch 15.

Van Soest, P. J., Robertson, P. J. & Lewis, B. A., 1997. Methods of dietary fibre, neutral detergent fibre, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74: 3583-3597.

Visser, K, 2013. Unpublished rainfall records for the farm Lovedale. Cited with permission.

Vlok, J.H.J., Cowling, R.M. & Wolf, T., 2005. A vegetation map for the Little Karoo. Unpublished maps and report for a SKEP project supported by CEPF grant no 1064410304

Vorster, M., 1986. Enkele weidingkundige aspekte van Karooveld en die effek daarvan op die veebedryf in die Karoostreek. Karoo Agric. 3(8), 12-6.

Vorster, M., 1999. Karoo and associated sweet Grassveld. In Veld management in South Africa. Ed. Tainton, N.M. University of Natal Press. Pietermaritzburg. p. 293-311.

Wallace, J.D., Hyder, D.N. & Van Dyne, G.M., 1972. Salivary contamination of forage selected by esophageal fistulated steers grazing sandhill grassland. J.Range Manage. 25(3), 185-188.

Wallis de Vries, M.F., 1995. Estimating forage intake and quality in grazing cattle. A reconsideration of the hand-plucking method. J. Range Manage. 48, 370-375.

Wan Zahari, M., Thompson, J.K., Scott, D. & Buchan, W., 1990. The dietary requirements of calcium and phosphorus for growing lambs. Anim. Prod. 50:301-308.

Watson, L. & Dallwitz, M.J., 1980. Australian grass genera. Anatomy, morphology and keys. Aust. Nat. Univ. Res. Sch. Biol. Sci., Canberra.

Webb. E.C., 1994. Synthesis of long chain fatty acids in ruminants and their effects on meat quality. Ph.D. thesis – University of Pretoria, 1994. Chapter 3, p58-59.

Weston, R.H., 2002. Constraints on feed intake by grazing sheep. In: Sheep Nutrition. CABI Publishing. Wallingford. Oxon. UK

Wilson, A.D., Weir, W.C. & Torell, D.T., 1971. Evaluation of chamise (*Adenostoma fasiculatum*) and interior live oak (*Quercus wislizeni*) as feed for sheep. J. Anim. Sci. 32:1042-1045.

Yoana, C., Newman, B.L. & Muir, J.P., 2006. Defining forage quality. IN: Nutritive Value of Southern Forages. Texas Agricultural Extension Services. SCS-2006-09.

Zeeman, P.J.L., Marais, P.G. & Coetzer, M.J., 1984. Nutrient selection by cattle, goats and sheep on natural Karoo pasture. 2. Nitrogen. S. Afr. J. Anim. Sci. 14:169.

Photo Appendix

Figure 50 Grassveld camp in the Bushmanland Arid Grassland Vegetation Type as described by Mucina *et al.* (2006), photo taken in April year 1

Figure 51 Grassveld was dominated by *Stipagrostis* species, photo taken in April year 1

Figure 52 Ranteveld camp in the Bushmanland Arid Grassland Vegetation Type as described by Mucina *et al.* (2006), photo taken in May year 1

Figure 53 Oesophageally fistulated sheep fitted with canvas collection bags grazing the Grassveld

Figure 54 Oesophageally fistulated sheep slowly being rounded up after sample collection in the Ranteveld

Figure 55 Oesophageally fistulated extrusa sample in canvas collection bag, note the shade cloth bottom which allows excessive saliva to pass through during sampling

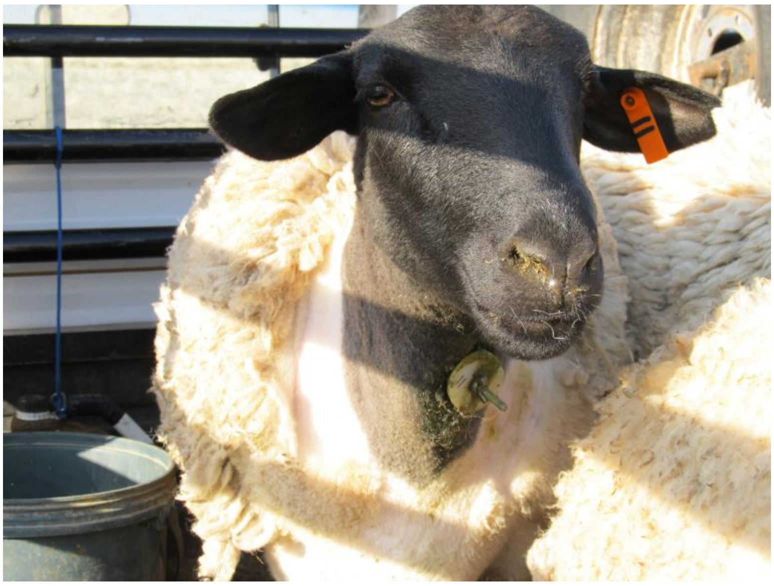

Figure 56 Oesophageally fistulated sheep after sample collection with fistula plug replaced.

Figure 57 Collection of rumen fluid from rumen cannulated sheep