Grass Species Composition, Distribution, Biomass Production Potential and Nutritional Value in Three Selected Communal Rangeland Areas Under Msukaligwa Local Municipality, Mpumalanga province

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DECLARATION

I, Thabile Joyce Mokgakane, hereby pledge that this dissertation is my original work and has not been previously submitted to any other University. All support, quotations and citations used throughout the development of this work have been acknowledged.

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ABSTRACT

Veld condition is dependent on abiotic and biotic factors such as vegetation dynamics, climatic conditions and soil characteristics. Therefore, this study assessed the spatial variation of grass species composition, distribution, biomass production potential and nutritive value from selected communal rangelands in Msukaligwa municipality, South Africa. The communal rangelands covered three different soil types (Breyten= Hutton), (Davel= Avalon), and (Wesselton= Clovelly). Grass composition and distribution were assessed using a 100 m permanent line point method, replicated three times at 50 m intervals. Grass species were recorded at 1 m marked point intervals within a 10 cm radius. Life form, palatability, ecological status and abundance data were recorded for all grass species found in each site. Hutton soil had high ($P<0.05$) concentrations (mg/kg) of $N\text{-}NO_3$, $N\text{-}NHO_4$, C, P, Cu, and Al compared to the same minerals recorded from Avalon and Clovelly soil types which had similar ($P<0.05$) concentration values. Hutton soil type also had the highest ($P<0.05$) percentage of palatable grass species (9.6%) and the lowest ($P<0.05$) percentage of unpalatable grass species (3.50%) compared to the Avalon and Clovelly soil types which had a lower ($P>0.05$) percentage of palatable and the highest ($P<0.05$) unpalatable grass species. No significant difference ($P>0.05$) was observed in biomass (kg/ha) yield across the three soil types. A variety of 31 grass species were found in all the three soil types, but only 6 were classified as common and dominant and were (*Aristida congesta, Digitaria eriantha, Eragrostis chloromelas, Eragrostis curvula, Eragrostis plana,* and *Eragrostis gummiflua*). These species were distributed across all soil types and were thus considered for nutritional characterization. *Digitaria eriantha*, *E. plana* and *E. gummiflua* in Hutton soil type had the highest ($P<0.05$) N values (17.0, 12.8 and 10.5 g/kg DM, respectively) when compared to the same species in other soil types. *Eragrostis chloromelas* in Avalon soil type had the highest ($P<0.05$) ADL concentration (189.3 g/kg DM) when compared to the same species in other soil types, which did not differ ($P>0.05$) significantly from each other. *Digitaria eriantha* on Hutton and Clovelly soil types had higher ($P<0.05$) Ca concentration (4.1 and 4.3 g/kg DM, respectively) when compared to all other species. *Eragrostis chloromelas* on Hutton and Clovelly soil types had higher ($P<0.05$) Fe concentration (259.2 and 186.3 g/kg DM, respectively) when compared to the same species on the Avalon soil type. With regards to *in vitro* ruminal fermentation, *E. chloromelas* on Clovelly soil had the highest ($P<0.05$) 36 h dry matter degradability (DMD) (649.3 g/kg DM) when compared to the same species on other soil types. Overall, the results showed that soil type did not affect the biomass yield. Although all communal study areas were not degraded, soil nutrient status such as C and N was lower on Avalon and Clovelly soil types. The results also indicate that soil type affected the chemical composition of grass. Nitrogen supplementation will be required for all soil types. This study provides farmers, researchers and agricultural advisors with information on grazing grass standards, rangeland conditions, species composition and, feeding value.

Keywords: Biomass yield, grass species, livestock farming, nutritive value, rangeland degradation and management, soil properties

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DEDICATION

This dissertation is dedicated to my family, my son Lunathi Mnisi, my husband Mduduzi Mnisi, my mother Joana Mokgakane, my sister Lindiwe Mokgakane and my two dearest brothers, Bongane and Surprise Mokgakane.

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LIST OF ABBREVIATIONS

ADF:	Acid Detergent Fibre
ADL:	Acid Detergent Lignin
AOAC:	Association of Official Analytical Chemists
ANOVA:	Analysis of Variance
Agri LASA:	Agri-Laboratory Association of Southern Africa
CP:	Crude Protein
CWC:	Cell Wall Constituents
CRD:	Completely Randomized Design
DM:	Dry Matter
DMD:	Dry Matter Degradability
GPS:	Geographical Positioning System
GVIs:	Grazing Index Values
GLM:	General Linear Model
Ha /LSU:	Hectares per Large Stock Unit
iDMD:	*in vitro* Ruminal Dry Matter Degradability
LSD:	Least Significant Difference
NDF:	Neutral Detergent Fibre
OM:	Organic Matter
OC:	Organic Carbon
SAS:	Statistical Analysis System
SE:	Standard error

1 CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background

Communal rangeland areas occupy about 13% of the agricultural land surface in South Africa (SA) while approximately 4.8% of them are classified as degraded (Vetter *et al.,* 2006). These rangelands are a major source of feed for livestock in most rural parts of South Africa (Teague & Dowhower, 2003). In the Msukaligwa municipality, communal livestock farmers are surrounded by well-managed commercial livestock farmers. This later farming system can be used as a benchmark for optimal communal rangeland management systems. However, increases in the number of beasts in communal rangelands result in its degradation (Jones *et al*., 2010). High numbers of animals cause overgrazing, which reduces palatable grass species while increasing the undesirable ones (Abusuwar & Ahmed, 2010). There are limited functional and operational rangeland management systems for livestock production in the communal rangelands (Tainton, 1999). Besides, recent climate uncertainty has made it difficult for communal livestock farmers to meet their livestock fodder requirements throughout the dry season (Shackelton *et al*., 2001). Maintaining the animal numbers following the rangeland grazing capacity is an essential grazing doctrine (Moreira *et al*., 2004). Over-exploitation, poor management practices, unpredictable climatic conditions and continuous grazing change the structure and basal cover of grass species. These changes lead to the loss of plant tissue and plant vigour, soil compaction and associated changes in the composition of the plant species (Kellner, 1995; An & Li, 2015).

1.2 Problem statement

Over-utilization and mismanagement of communal grazing rangelands are a threat in the rural parts of SA (Du Preez, 1995; Little *et al*., 2015). Also, the area of land that is available for rangeland is shrinking due to a steady increase in other forms of land use (Grant, 1995; Coetzer *et al*., 2010). The rangeland conditions are deteriorating, a process that fundamentally affects the welfare of those who depend on land as a basic resource for livestock production (Abusuwar & Ahmed, 2010). Sustainable production of livestock in communal areas is highly dependent on the knowledge of vegetation species in terms of their composition, distribution, production and nutritive values for effective utilization of the rangelands for both short and long-term benefit (Beyene & Mlambo, 2012), however, this information is not available for the communal rangelands of Msukaligwa municipality. Therefore, understanding the spatial variation of the herbaceous layer composition, distribution, biomass production potential and nutritive value in these communal areas would assist with sustainable livestock production and land management (McGranahan & Kirkman, 2013).

1.3 Justification of the study

Recently, the emphasis has shifted to identifying and implementing management systems that control the degree of utilization by manipulating grazing procedures. Since the veld condition is reliant on abiotic and biotic factors that are unpredictable and inconsistent, implementing effective management systems is required to improve the current management system of vegetation (McGranahan & Kirkman, 2013). These approaches can be implemented if knowledge of species composition, distribution, biomass production potential and nutritive value is available. The current study will enable communal livestock farmers to restore rangelands and thus improve animal output sustainably. The study generates baseline information on the variation of grass density, distribution, biomass production potential, and other indices of species composition as well as the nutritive value of vegetation useful to communal farmers and agricultural advisors for better rangeland and livestock management.

1.4 Aim and objectives of the study

This study aims to assess and compare the grass species composition, distribution, biomass production potential and nutritional value of three communal rangelands (Breyten, Davel, and Wesselton) in Msukaligwa municipality, Mpumalanga province. The objectives of this study were:

1. To assess the spatial variation of grass species composition, distribution and biomass production potential from selected communal rangelands in Msukaligwa municipality.
2. To assess the effect of soil type on biomass production and nutritive value of the identified grasses from selected communal rangelands in Msukaligwa municipality.
3. To determine the effect of soil type on *in vitro* ruminal fermentation of the grass species from selected communal rangelands in Msukaligwa municipality.

1.5 Research questions

1. What is the spatial variation in grass species composition, distribution, nutritive value and biomass production potential harvested from the selected communal rangelands in Msukaligwa municipality?
2. Does the soil type affect biomass yield and the nutritive value of grass?

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2 CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Herbaceous vegetation exists as the most common source of nutrients for both browsing and grazing animals, even though this is rarely sufficient for optimum livestock production (Espinoza *et al.,* 1991). Communal rangelands face numerous threats that are considered to be difficult to evaluate and mitigate, leading to poor management and rangeland degradation (FAO, 2009). The types of livestock production systems practised in a community tend to influence the condition of communal rangelands (Teague & Dowhower, 2003). In communal areas, rangeland is usually shared by community members, and everyone within that community has access to rangeland resources (FAO, 2005). Communal farmers have an equal right to access rangeland, even though their purposes for keeping livestock vary, facing over-utilization of rangeland resources by grazing animals because of the high livestock numbers is a huge challenge in communal areas (FAO, 2005). Katjiuna & Ward (2007) found that over-utilization of rangeland resources through overgrazing leads to an increase in undesirable plants and the loss of rangeland resources through overgrazing in communal areas has been linked to poor rangeland management because communal areas have unclear land tenure. Grazing resources are poorly managed in communal areas because of communal ownership of the resource and free access of livestock to grazing and water points (Botswana Government, 1975).

2.2 Livestock in communal lands

Communal areas often have production systems that are grounded in pastoralism and agro-pastoralism with an uneven herd proportion within and between regions. Livestock production contributes between 5-6% of formal agricultural output in SA plus mixed livestock ownership is often traditionally practiced in the communal grazing system (Wigley *et al*., 2010; Chiepe *et al*., 2017), where herbivory (both wild and domestic) has a crucial influence on available species composition and biomass (Palmer & Ainslie, 2007). Mapiye *et al*. (2009) and Morokong *et al*. (2016) have reported that parasites, feed shortages, and diseases are the major factors that limit the production of cattle in most communal areas.

Proper management of rangeland resources is vital in communal rangelands due to several aspects including stocking rates, maintaining seasonal grazing, and communal farmers are also dependent on the native grass for livestock production (Chiepe *et al*., 2017). However, over-stocking, bush encroachment, land degradation, poor management, overgrazing, uncontrolled animal movement, and damage of palatable vegetation remain as problems accompanying communal lands (Fatunbi & Dube, 2008a). In SA, three types of livestock production systems are commonly practiced, that is communal commercial ranching, game reserves, and livestock grazing (Tefera *et al*., 2008). However, these systems have some loop-holes/gaps, regardless of communal rangelands having multiple managers, but to some extent, there is a lack of proper management and maintenance (Hungwe, 2014). Through the continuous grazing system, people from the rural areas maintain a variety of livestock in their communal rangelands, for these reasons, the stocking rate exceeds the carrying capacity (Van der Westhuizen *et al*., 2005). Over-grazing is considered to be an increasing concern for communal rangelands (Fatunbi & Dube, 2008b). Due to the extensive farming system commonly practised in the communal lands, it is necessary to safeguard and address fairness in terms of access to land use. Management strategy normally helps to recover and sustain palatable vegetation on the land (Smet & Ward, 2005; Scholtz *et al*., 2013).

2.3 Importance of grasses in communal areas

Grass serves as feed for livestock while it provides a habitat to wild animals (Jacobs *et al*., 1999; Little *et al*., 2015). In terms of the global carbon cycle, some studies have reported that grasses cover about 25.4% land area, helping to retain 10-30% soil organic carbon (SOC) while being a sink for more than 10% carbon found in surface-dwelling biomass (Schlesinger, 1997; Scurlock & Hall, 1998; An & Li, 2015). The conditions for grassland biomes in SA are constantly changing; with about 60% completely transformed, 25% degraded grassland, 15% natural grassland, and 2% properly conserved grassland. Unfortunately, after major disturbances, recovery is inefficient and slow (Carbut *et al*., 2011; Little *et al*., 2015). Livestock and wildlife receive their main forage from rangelands and supplementary feed from fodder crops, dryland and irrigated pastures (Beyene & Mlambo, 2012). Proper management of rangeland resources is vital for SA's economy since the country exports rangeland-derived products such as meat and milk.

2.4 Nutritional composition of grasses

Providing essential nutrients in animal diets is vital for optimal performance. The diet is expected to provide nutrients to support optimum metabolism and rumen microbial protein synthesis (Manyedi *et al*., 2017). Rumen ungradable protein (RUP) is also considered an important source for amino acids for high-producing ruminants (Reid *et al*., 2015). Fibre degradability is known to be associated with the chemical composition, such as the CP and NDF content that are, in turn, affected by age of grass.

Huws *et al*. (2014) reported an inversely proportional relationship between DM degradability and the concentrations of CP, lignin, hemicellulose and cellulose. Lignin was identified as a limiting factor for degradability, but not for most feed constituents (e.g. non-cell wall constituents). These findings indicate that lignification of cell wall polysaccharides is a major factor that affects the DM degradability rate of grasses (Van Soest *et al*., 1991; Jung & Allen, 1995).

2.5 Veld condition assessment

Species composition is reported to be the comparative proportion of different species found in a certain rangeland, it is widely used as an indicator for rangeland conditions including communal rangelands, due to the accessibility of varied ruminants with different palatability preferences (Abule et al., 2007). Livestock production systems rely on well sustained, functionally diverse grass species composition. This highlights the need for maintenance and advanced management practises to sustain the availability of a diverse species composition. Overgrazing is repeatedly reported as an observed land-stressing tendency among many communal rangelands in South Africa due to long uncontrolled supervision of grazing animals (Snyman, 2009).

Rangeland condition is a measure of how existing plant communities can support livestock while protecting the soil (Holechek *et al*., 2001; Angassa *et al*., 2006). The veld condition assessment is required to gauge whether special management techniques are necessary to maximize rangeland products (Rasaei *et al*., 2006). Numerous features influence the condition of a veld such as the basal cover, grazing intensity, species composition, elevation, soil type, surface conditions, grazing intensity, and changes in palatable species composition, seasonal variation in rainfall as well as climate conditions (Camp, 1999; Angassa *et al*., 2006). According to Camp (1999), based on the above-mentioned factors, only species composition can be quantitatively measured. Whereas Van Oudsthoorn (2004), considered that the grasses' ecological status can be of importance in defining a veld's condition, including that the benchmark sites are influenced by the species composition of the common and dominating samples from the veld, and also evaluated that a benchmark site should at least be able to sustain animal production. According to Tainton (1999), a conflict between agronomic and ecological approaches to veld condition assessment should occur only in certain specific situations.

2.5.1 Forage response on grazing

Grazing is known to impact on soil nutrient dynamics and foliage accumulation, thus causing the grassland ecosystems to shift (An & Li, 2015). According to Palmer & Ainslie (2007), livestock in SA depends on grazing in rangelands as a source of forage with about 68.6% of the rangelands being used for livestock grazing and about 9.6% being used for wild herbivore grazing. Bennett & Barrett (2007), recognized that in most communal zones across Africa, there are three commonly practised systems of grazing management, which are; grazing on private land owned by the landlord, grazing on public access ranges, and grazing on community-owned ranges. Depending on the size of the grazing area (preferably large), labour conditions, and capital being considered for grazing management, the above-mentioned systems could be regarded as extensive grazing systems (Allen *et al*., 2011).

Complete removal of green leaves will make initial regrowth dependent on carbohydrate reserves, resulting in a slowing down of growth after clipping. However, different species can react differently to the altered intensities of defoliation throughout the year (Tainton, 1999). According to Danckwerts (1984), the green leaf remaining after defoliation is imperative for regrowth, and the species may grow side by side with other species, but they prefer very different defoliation regimes. A study by Lutge *et al*. (1996) was undertaken in tall grassland of KwaZulu-Natal and found that some grass species tufts in already established heavily grazed patches were shown to have significantly lower growth potential at the beginning of the growth period than tufts situated in non-grazed patches. Peddi *et al*. (1995) suggested that to restore the vegetation in the grazing area, having a resting season could be an effective strategy.

The root biomass is affected by heavy grazing through trampling, which may lower the productivity of livestock by dropping the availability of soil nutrients, disturbing the structure of the soil and its surface crust leading to soil erosion (Neff *et al*., 2005; Savadogo *et al*., 2007; Wigley *et al*., 2010).

2.5.2 Rangeland deterioration

Over-exploitation and poor management practices coupled with unpredictable climate conditions, especially the rainfall patterns led to the degradation of natural rangelands in the climax grass veld of Southern Africa (Kellner & Bosch, 1995). During the process of degradation, changes in the composition and basal cover of the species are used for the condition assessment of the veld by a degradation gradient model. Species are classified in the ecological status group (Increaser and Decreaser type of species) and it is therefore known, that a certain vegetation composition represents a particular state of rangeland (Holechek *et al*., 2001). The successional changes that take place by the species from one condition to another are, however, unknown. According to Du Preez (1995), over-utilization and mismanagement of most abundant land are common occurrences in most of the former homelands of SA, which results in over-exploitation of the natural resources. Other factors influencing the deterioration of accessible grazing rangelands include the increasing human population (more land is needed to accommodate the people), people maintaining a mixture of livestock species through a continuous grazing system, tribal wars based on land ownership resulting in a vague authority of the land, privatization of land, removal of existing vegetation, low water availability, cultivation (more land is used to supply the increasing food demands), high stocking rate above the carrying capacity, no grazing strategy or management, high grazing pressure together with accessibility (Moleele & Perkins, 1998; Camp, 1999; Ahmad & Islam, 2011). The soil nutrients and grass layer productivity are observed to be altered due to over-grazing. However, keeping different livestock species allows the efficient exploitation of vegetation (Tefera *et al*., 2007).

2.6 Summary

The grass is essential in livestock feeding but it becomes less palatable and digestible as it matures due to high fibre and lignin concentrations as well as low protein and soluble carbohydrate concentrations. High stocking rates in communal rangelands have reduced plant cover resulting in low plant diversity and rangeland degradation. Overgrazing leads to palatable species extinction and poor livestock productivity. It is, therefore, important to generate information that assists farmers in optimally managing their rangelands. Such information, which is lacking in several communal areas of South Africa, includes soil characteristics, grass species and their distribution, the nutritive value of grasses, and grazing standards.

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3 CHAPTER THREE: GRASS SPECIES COMPOSITION, DISTRIBUTION AND BIOMASS PRODUCTION POTENTIAL IN SELECTED COMMUNAL RANGELANDS IN MSUKALIGWA MUNICIPALITY

Abstract

Veld condition is dependent on abiotic and biotic factors such as vegetation dynamics, climatic conditions, and soil characteristics. This study was, therefore, designed to provide baseline data by assessing the spatial variation of grass species, species distribution and their biomass production potential in selected communal rangelands in Msukaligwa municipality. The communal rangelands spanned three different soil types (Breyten = Hutton soil type; Davel = Avalon soil type and Wesselton = Clovelly soil type). Nine soil samples per site were collected from a depth of 200 mm with three samples being taken from the topsoil of each area. The soil samples were dried at 25°C room temperature, then sieved using a 2 mm mesh screen for chemical analysis according to the Agri-Laboratory Association of Southern Africa (AgriLASA) procedures. Grass species composition and distribution were assessed using a 100 m permanent line point method, replicated three times, 50 m apart. Grass species were recorded at 1 m marked point intervals within a 10 cm radius. Life form, palatability, ecological status and abundance data were recorded for all grass species found in each site. Under life form, 90% grass species were found to be tufted perennial, 6.5% were found to be weak perennial and 3% were creeping grass species. Avalon soil had higher ($P<0.05$) pH (4.49) than Hutton (3.62) and Clovelly (3.55) soils. Hutton and Clovelly soils had higher ($P<0.05$) carbon values (1.56% and 1.29%, respectively) when compared to Avalon soil (0.473%). Hutton soil had the highest ($P<0.05$) potassium concentration (110.67 mg/kg) followed by Avalon (91.33 mg/kg). Clovelly soil had the highest ($P<0.05$) iron concentration (135.90 mg/kg) followed by Hutton (74.63 mg/kg) and Avalon (53.33 mg/kg) soils. From the three soil types, an overall of 31 different grass species was obtained. *Cynodon dactylon* was more common in Avalon, dominant in Clovelly soil and rare in Hutton soil type. *Digitaria eriantha* was more common in Clovelly, dominant in Hutton soil and very rare in Avalon soil. *Paspalum dilatatum* was common in Clovelly soil, rare in Hutton soil type and present in Avalon soil type, respectively. There was no significant difference ($P>0.05$) in biomass yield (kg/ha) across the three soil types. Hutton soil type had the highest ($P<0.05$) proportion of palatable grass species (9.6%) and also the lowest ($P<0.05$) proportion of unpalatable grass species (3.50%). The results show that soil type has no effect on the biomass yield of grasses but affected the proportion of palatable grass species. Although none of the communal areas studied were degraded, soil nutrients such as carbon and nitrogen were lower in Avalon and Clovelly soil types.

Keywords: Biomass production, grazing capacity, palatability, rangeland condition, soil type, soil nutrition

3.1 Introduction

Rangeland degradation is of major concern in South Africa (Danckwerts & Tainton, 1996; Hoffman & Ashwell, 2001). This is because vegetation cover is crucial in landscape preservation as it shields the soil from harsh temperatures, winds, and rainfall (Fatunbi & Dube, 2008a). There is heterogeneity in arid and semi-arid ecosystems caused by the varied biomass, density, composition, and vegetation structure and this influences the functioning of the ecosystem (Moyo *et al*., 2010; Wang *et al*., 2016). Rangeland soil erosion is affected by particle size distribution (Snyman, 1999) and is influenced by several factors such as soil sealing, climatic changes, elimination of vegetation cover, and loss of soil aggregates (Fatunbi & Dube, 2008b). In SA, livestock farming tends to use the largest portion of land in most rangelands, and also uses land resources by converting high fibre vegetation biomass into valuable animal protein sources (Scholtz *et al*., 2013). Unfortunately, the species composition in rangelands may be drastically changed from perennials to annuals leading to a reduction in veld production and quality through continuous selective grazing (Snyman, 2004; O'Connor *et al*., 2010). Therefore, an evaluation of the veld condition is essential to warrant the productivity and quality of the veld, as it helps landowners and livestock farmers in maintaining and applying appropriate management strategies (Milton & Dean, 1996). Understanding the species composition, distribution, and biomass production potential is important to manage and sustain grazing rangelands for livestock production (Van Langevelde *et al*., 2003). Knowledge of the condition of rangelands in areas with different soil types is also critical for developing sustainable rangeland management procedures (Scollan *et al*., 2010). However, this information is not available for several communal rangelands such as those in the Msukaligwa municipality, Mpumalanga province. Therefore, the objective of this study was to assess and compare the grass species distribution, biomass production potential, and composition in Msukaligwa municipality.

3.2 Materials and methods

3.2.1 Study sites

The study was carried out in three communal rangeland sites in the Gert Sibande District, Msukaligwa municipality, South Africa, shown in Figure 3.1. The three selected communal rangeland areas are Breyten, Davel and Wesselton, which are all approximately ±30 km apart. These locations were selected based on their soil type variations. The soil form and geological structure of the above areas vary considerably, wherein Breyten geological substrate mainly consists of the Transvaal Supergroup, which gives rise to a Hutton dominant soil form. Davel geology consists of the Ecca group – a sub-group of the Karroo Supergroup overlain by Avalon soil form. Whereas Wesselton geology is dominated by the Drakensberg Supergroup overlain by Clovelly soil form (Table 3.1). Breyten site (S26° 29' 59.000" E 30° 12'. 000") is situated approximately 30 km away from Wesselton site (S26 °30'38.182" E 29 °57'38.451") which is within 5 km of Ermelo town and they also had similar vegetation which is covered by the Eastern Highveld Grassland (Mucina & Rutherford, 2006). Both areas vary with the average altitude between 1629 and 1704 m above sea level. However, Davel site (S26° 46' 8.000"E 29° 66'52.000") is situated approximately 40 km away from Ermelo town and its vegetation type is covered by Soweto Highveld Grassland (Mucina & Rutherford, 2006), with an average altitude of 1715 metres above sea level. Rainfall for all study areas varies from 662-726 mm/ annum, with the mean daily temperature ranging from 6º C in winter to 24º C in summer. Highveld can be classified as mainly sour grassland and provides high grazing quality in spring and summer seasons, whilst during autumn the quality of the grazing slowly decreases, however winter grazing contains little nutrients due to the translocation of nutrients to the roots (Acocks, 1988). Livestock kept in the study areas are beef cattle, sheep, goats, horses and donkeys. This study complies with the North-West University Ethics Committee standards and was given the ethical clearance number: NWU-00658-18-A5.

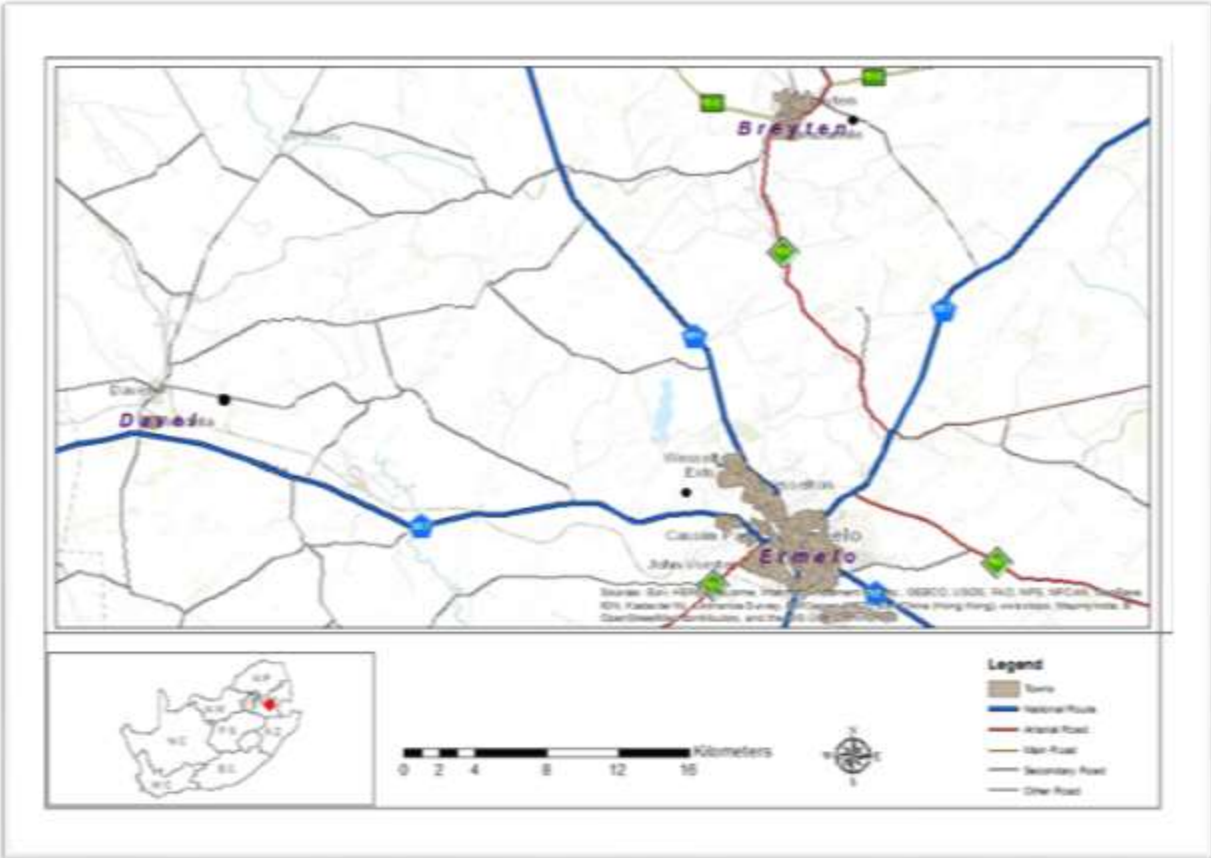

Figure 3.1: Geographical positions of the study sites in Gert Sibande District, Msukaligwa municipality

3.2.2 Site layout

Table 3.1 shows the study areas' site coordinates, altitude, soil form, and vegetation. The rangelands were selected based on soil types.

Table 3.1: Study area coordinates, altitude, soil form, and vegetation

Study area	Coordinates	Altitude (m)	Soil form	Vegetation
Breyten	26° 29' 59.000" S 30° 12'. 000" E	1704	Hutton soil (Hu)	Eastern highveld Grassland (Gm12) (Mucina & Rutherford 2006)
Davel	26° 46' 8.000" S 29° 66'52.000" E	1715	Avalon soil (Av)	Soweto Highveld Grassland (Gm8) (Mucina & Rutherford 2006)
Wesselton	26 °30'38.182" S 29 °57'38.451" E	1629	Clovelly soil (Cv)	Eastern highveld Grassland (Gm12) (Mucina & Rutherford 2006)

3.2.3 Soil sampling

Three transects per site were taken when collecting topsoil samples at a depth of 200 mm, which resulted in a total of nine samples per area. The samples were further air-dried, ground and sieved using a 2 mm mesh screen for data analysis. The standard Bouyoucos (hydrometer) method was used to determine the soil's texture (Day, 1965). The soil/ water relation extraction method was used to measure the pH of the soil with a 1: 2.5 ratio. The total nitrogen (N) was determined by using the Kjeldahl method (Van Reeuwijk, 1992). The colorimetric method was used to determine the total organic carbon (OC) (Baker, 1976). The macro and micro-minerals were analysed according to the agricultural laboratory association procedures (AgriLASA, 1998).

3.2.4 Grass sampling

A 100 m permanent line point method was used. The permanent lines were replicated three times, 50 m apart within each site. Grass species at 1 m marked point intervals and within a 10 cm radius were identified at each site. At each site, shoot height, and diameter were recorded. All grass species found in each site were classified according to their life form, palatability, ecological status, and their abundance from all the grazing areas.

3.2.5 Species identification and classification

Grass species were identified and classified with the information being recorded using a special field form template. All grass species that were found in each site were classified according to their life form, palatability (desirability), ecological status and their abundance from all the grazing areas. In terms of abundance status, a grass species was classified as dominant (D), if its density was more than 13%, common (C), if its density ranged between 3 and 13%, rare (R), if its density ranged between 1 and 3% or as present (P) if its density was found to be less than 1%. According to Van Oudtshoorn (2014), the grass species were grouped based on their ecological status (decreasers, D, which are grasses found to be abundant in the veld but tend to decline due to overgrazing; increaser, I, grasses that are abundant in under-utilized veld; increaser, ii, grasses that are abundant in an over-grazed veld; increaser, iii, are referred to as those species that are found to be common when the veld is over-grazed and invaders, which are those species that are not indigenous and rarely play an ecological nice in the area). The grasses were classified according to the desirability group (highly palatable (HP), moderately palatable (MP) and non-palatable (NP)). Sampling sites were geo-referenced using a GPS device. The grasses were identified using Van Oudtshoorn (2014)'s guide to grasses of Southern Africa. The checklist for Southern African plants was used for the verification of genus and species names (Germishuizen *et al*., 2006). Above-ground biomass was measured and harvested from transects at 20 m intervals using a falling plate meter (disc pasture meter). Shoot height and diameter were measured using a ruler in (cm). The plant species cover and the grazing index values (GIVs) were used to determine the grazing capacity (ha/LSU) according to Du Toit (1995). The grazing capacity (LSU/ha) was calculated using the following equation:

$$Y = \mathrm{d} \div \frac{[\mathrm{DM\ x\ F}]}{\mathrm{r}}$$

Whereby; Y = grazing capacity (ha/LSU), d = the number of days in a year, DM = dry matter yield/ biomass (kg/ha), F = utilization factor (0.5), r = dry matter required daily by animal (450 kg). Dry biomass production was rated as poor (500 - 2000 kg/ha), fair (2001 - 4000 kg/ ha) and good (4001 - 6000 kg/ha).

3.2.6 Statistical analysis

The effect of soil type on chemical elements, biomass, grass species composition, desirability group, and grass species occurrence was evaluated by analysis of variance using the Statistical Analysis System (SAS 2010). The means were separated and compared using the Least Significant Difference (LSD) calculated at p = 0.05 level. The below formula was used:

$$Yij = \mu + Si + \varepsilon ij$$

From the model, Yij=dependent variable, Where μ =is overall mean, Si = site effect, εij = error linked to a random observation accepted as an independent and normal distribution.

3.3 Results

3.3.1 Soil parameters

Table 3.2 presents the properties of different soils found in the selected communal rangelands. Avalon soil type had the highest (P<0.05) pH value (4.5), whereas Hutton (3.6) and Clovelly (3.5) soil types had similar (P>0.05) pH values.

Table 3.2: Properties of different soil types found in selected communal rangelands

Soil properties	Soil type			
	Hutton soil	Avalon soil	Clovelly soil	SEM
pH value	3.6^{b}	4.5^{a}	3.5^{b}	0.240
Nitrogen nitrate (mg/kg)	0.770^{a}	0.533^{b}	0.030^{c}	0.027
Nitrogen-peroxynitric acid (mg/kg)	4.8^{a}	5.2^{a}	5.2^{a}	0.129
Carbon (%)	1.6^{a}	0.5^{b}	1.3^{a}	0.117
Extractable acidity (%)	0.900^{a}	0.280^{c}	0.573^{b}	0.022
Extractable Alkalinity (%)	0.7^{a}	0.3^{c}	0.327^{b}	0.018
Sand (%)	76.3^{ab}	74.3^{b}	77.7^{a}	0.882
Silt (%)	9.3^{a}	9.0^{b}	9.0^{a}	0.609
Clay (%)	13.7^{b}	15.7^{a}	12.3^{c}	0.333
Macro-minerals (mg/kg)				
Potassium	110.7^{a}	91.3^{b}	79.0^{c}	3.5
Calcium	233.0^{c}	486.7^{a}	401.7^{b}	6.5
Magnesium	91.3^{b}	107.7^{a}	112.7^{a}	2.8
Phosphorus	3.3^{b}	9.3^{b}	10.3^{a}	2.2
Sodium	3.7^{b}	2.7^{b}	28.0^{a}	0.720
Micro-minerals (mg/kg)				
Iron	74.6^{b}	53.3^{c}	135.9^{a}	5.5
Copper	2.8^{a}	1.4^{c}	2.4^{b}	0.1
Zinc	1.6^{c}	3.7^{b}	11.5^{a}	0.3
Aluminum	54.6^{a}	9.4^{c}	27.7^{b}	0.483
Manganese	25.3^{b}	28.5^{ab}	32.1^{a}	1.1

[abc] Means different lowercase superscripts in the same row are significantly different ($P<0.05$).
SEM: Standard error of the mean.

Hutton soil type had the highest ($P<0.05$) $N\text{-}NO_3$ concentration (0.770 mg/kg) than Clovelly (0.030 mg/kg) and Avalon (0.533 mg/kg) soil types. All soils had similar ($P>0.05$) $N\text{-}NHO_4$ concentration. Hutton and Clovelly soil types had similar ($P>0.05$) C concentrations, however, Avalon soil had a lower ($P<0.05$) C value (0.5%). Hutton soil had the highest ($P<0.05$) K concentration (110.7 mg/kg). Avalon soil had higher ($P<0.05$) Ca concentration

(486.7 mg/kg), whereas Hutton soil had the lowest (P<0.05) Ca (233.0 mg/kg) concentration. Clovelly soil type had the highest (P<0.05) P (102.3 mg/kg) concentration.

3.3.2 Grass species composition and distribution

Results on life form, ecological status, palatability, and abundance of grass species found in the selected communal rangelands of Msukaligwa local municipality under different soil types are presented in Table 3.3. From this study, 31 different species were found and classified. Between them, 28 grass species were classified as tufted perennials, two grass species were identified as weak perennials, and one grass was identified as a creeping grass. Sixteen percent of these grass species were identified as highly palatable, 39% as moderately palatable, 32% as unpalatable while 13% could not be categorized. *Andropogon schirensis, Harpochloa falx, Stiburus alopecuriodes, Elionurus muticus, Eragrostis planiculmis* and *Urochloa paniciodes* were all found to be common in Hutton soil type and present in Avalon and Clovelly soil types. *Eragrostis plana* was found to be common in Hutton soil type and dominant in Avalon and Clovelly soil types. *Ctenium concinnum, D. amplectens, E. capensis,* and *M. ceresiiforme* were found to be rare in Hutton soil type and present in Avalon and Clovelly soil types. *Cynodon dactylon* and *E. chloromelas* in Clovelly soil type had a higher (P<0.05) distribution percentage than the same species in other soil types. *Digitaria eriantha, E. racemose, H. contortus,* and *T. triandra* had the highest (P<0.05) distribution percentage when matched to the same species in the other soil types.

Table 3.3.3: Life form, ecological status, grazing values, and distribution of grass species based on the soil types

Grass species	Life form[1]	Ecological status[2]	Grazing value[3]	Abundance[4]		
				Hutton soil	Avalon soil	Clovelly soil
Aristida congesta	WP	Inc ii	NP	C	C	R
Andropogon schirensis	TP	Inc i	MP	C	P	P
Brachiaria serrata	TP	Dec	MP	P	P	P
Ctenium concinnum	TP	Inc i	NP	R	P	P
Cynodon dactylon	CG	Inc ii	HP	R	C	D
Digitaria amplectens	TP	Dec	MP	R	P	P
Digitaria eriantha	TP	Dec	HP	D	R	C
Digitaria setifolia	TP	Inc ii	NS	P	P	P
Eragrostis capensis	TP	Inc ii	MP	R	P	P
Eragrostis chloromelas	TP	Inc ii	MP	C	C	D
Eragrostis curvula	TP	Inc ii	MP	C	D	C
Eragrostis gammiflua	TP	Inc ii	NP	R	C	C
Eragrostis micrantha	TP	Inc ii	NS	R	R	P
Elionurus muticus	TP	Inc iii	MP	C	P	P
Eragrostis plana	TP	Inc ii	NP	C	D	D
Eragrostis planiculmis	TP	Inc ii	NS	C	P	P
Eragrostis racemosa	TP	Inc ii	MP	C	P	R
Eragrostis rigidior	TP	Inc ii	MP	D	P	P
Heteropogon contortus	TP	Inc ii	MP	C	P	R
Harpochloa falx	TP	Inc i	NP	C	P	P
Hyparrhenia hirta	TP	Inc i	MP	P	C	R
Microchloa caffra	TP	Inc ii	NP	R	P	P
Monocymbium ceresiiforme	TP	Dec	MP	R	P	P
Paspalum dilatatum	TP	EG	HP	R	P	C
Stiburus alopecuriodes	TP	CG	NP	C	P	P
Sporobolus africanum	TP	Inc ii	NP	R	R	P
Setaria sphacelata	TP	Dec	HP	P	P	R
Trichoneura grandiglumis	WP	Inc ii	NP	R	P	P
Tristachya leucotrix	TP	Dec	MP	C	P	R
Themeda triandra	TP	Dec	HP	C	P	C
Urochloa paniciodes	TP	Inc ii	NP	C	P	P

[1]Life Form: TP = Tufted perennial, WP = Weak perennial.

[2]Ecological Status: CG = Creeping grass, Inc I = Increaser i, Inc ii = Increaser ii, Inc iii = Increaser iii, Dec = Decreaser, EG = Exotic grass, CG = Climax grass.

[3]Grazing value: NP = Not palatable, MP = Moderately palatable, HP = Highly palatable.

[4]Abundance: D = Dominant (>13%), C = Common (>3-13%), R = Rare (1-3%), P = Present (<1%).

Table 3.4 presented the results on grass species composition (%) based on frequencies of occurrence for common and dominant grasses found on the different soil types. *Cynodon dactylon* (13.8%) and *E. chloromelas* (15.9%) in Clovelly soil type had higher ($P<0.05$) distribution percentages when compared to the same species in other soil types. In Hutton soil type, *Digitaria eriantha*, *E. racemosa*, *H. contortus*, and *T. triandra* had the highest ($P<0.05$) distribution percentages compared to the same species in other soil types. *Eragrostis plana* in Avalon soil type had a higher ($P<0.05$) distribution percentage (24.1%) than the same species in other soil types. *Eragrostis plana* in Hutton soil type had the least ($P>0.05$) distribution percentage (9.1%).

Table 3.4: Composition (%) based on frequencies of occurrence for common and dominant grass species found in the soil types

	Soil types			
Grass species	Hutton	Avalon	Clovelly	SEM
Aristida congesta	6.7[a]	5.3[a]	1.9[b]	1.1
Andropogon schirensis	0.22[a]	0.01[b]	0.01[b]	0.44
Cynodon dactylon	2.6[c]	8.5[b]	13.8[a]	1.7
Digitaria eriantha	12.8[a]	2.55[b]	3.7[b]	0.92
Eragrostis chloromelas	8.3[b]	11.3[b]	15.9[a]	1.6
Eragrostis curvula	4.0[c]	20.7[a]	12.6[b]	1.6
Eragrostis gammiflua	1.7[b]	10.00[a]	11.8[a]	1.4
Eragrostis micrantha	0.01[a]	0.01[a]	0.01[a]	0
Elionurus muticus	4.0[a]	0.01[b]	0.01[b]	0.62
Eragrostis racemosa	7.6[a]	0.630[b]	0.01[b]	0.23
Eragrostis plana	9.1[c]	24.1[a]	16.7[b]	1.9
Eragrostis rigidior	0.89[a]	0.01[b]	0.01[b]	0.15
Heteropogon contortus	8.7[a]	0.01[b]	1.0[b]	0.88
Harpochloa falx	3.3[a]	0.01[b]	0.01[b]	0.3
Hyparrhenia hitra	0.01[b]	9.37[a]	0.01[b]	0.58
Paspalum dilatatum	0.01[b]	0.01[b]	3.4[a]	1.6
Stiburus alopecuriodes	2.2[a]	0.01[b]	0.01[b]	0.64
Setaria sphacelata	0.01[a]	0.01[a]	0.74[a]	0.27
Tristachya leucotrix	6.2[a]	0.01[b]	0.01[b]	0.65
Themeda triandra	12.3[a]	0.01[c]	6.5[b]	1.5
Urochloa paniciodes	0.78[a]	0.01[b]	0.01[b]	0.22

[abc] Same lowercase superscript letters within the same row represent a non-significant difference between soil types (P>0.05).
SEM: Standard error of the mean.

3.3.3 The desirability of grass species

Differences of desirability are recorded as the percentages of grass species classified as highly palatable, moderately palatable, and unpalatable according to their potential value for livestock production in the three grazing areas are presented in Table 3.5. Clovelly soil type had the same (P>0.05) proportion of highly palatable grass species as on Hutton and Avalon soil types which were significantly (P<0.05) different between each other. Avalon soil type had the highest (P<0.05) amount of moderately palatable species when compared to Hutton and Clovelly soil types, which did not differ (P>0.05) from each other. Avalon soil type had the same proportion of unpalatable species as Hutton and Clovelly soil types which themselves differed (P<0.05).

Table 3.5: Grass species desirability (%) across three soil types

	Soil type			
Species desirability	Hutton soil	Avalon soil	Clovelly soil	SEM
Highly palatable	9.63^{a}	4.83^{b}	6.27^{ab}	1.06
Moderately palatable	3.83^{b}	13.60^{a}	5.06^{b}	0.358
Unpalatable	3.50^{b}	6.87^{ab}	7.70^{a}	0.978

^{ab} Means different lowercase superscript letters in the same row are significantly different (P<0.05).
SEM: Standard error of the mean.

3.3.4 Biomass production and grazing capacity

The results on herbaceous biomass production (kg/ha) and grazing capacity of grass species growing in the selected communal rangelands under different soil types are shown in Table 3.6. No significant (P>0.05) difference was found on herbaceous biomass production and grazing capacity from all the selected areas. All the areas had high herbaceous biomass yields of more than 4000 kg/ha, with Avalon soil producing 4110.7 kg/ha and Hutton soil producing 5159.1 kg/ha. The calculated grazing capacity was 1.25 times lower on Avalon soil compared with Hutton soil and Clovelly soil.

Table 3.6: Biomass production (kg/ha) of grass species and estimated grazing capacity across soil types

Soil type	Biomass (kg/ha)	Grazing capacity (ha/LSU)
Hutton soil	5159.1	1.6
Avalon soil	4110.7	2.0
Clovelly soil	5113.3	1.6
SEM	392.38	

SEM: Standard error of the mean.

3.3.5 Grass height

The results on the height of common and dominant grass species found growing in the three soil types are presented in Table 3.7. *Aristida congesta* grass species growing on Avalon and Clovelly soil types were taller (P<0.05) compared to Hutton soil type (38.7 cm). *Eragrostis chloromelas* plants growing on Hutton soil type (64.6 cm) were the tallest (P<0.05) followed by those on Clovelly (52.8 cm) and Avalon (25.1 cm) soil types. *Digitaria eriantha* plants growing on Avalon soil type were taller (35.1 cm, P<0.05) when compared to the same species on Clovelly and Hutton soil types, whose height did not differ. *Eragrostis* c*urvula* species were of similar (P>0.05) height across all soil types. *Eragrostis gummiflua* plants growing on Clovelly soil type were taller (P<0.05) than the same species growing on Clovelly and Avalon soil types, which did not differ. *Eragrostis plana* plants growing on

Clovelly (48.4 cm) and Hutton (46.3 cm) soils were taller (P<0.05) than those on Avalon soil type (33.1 cm). *Themeda triandra* plants growing on Hutton soil type were taller (52.1 cm, P<0.05) than those growing on Clovelly soil type (30.3 cm).

Table 3.7: Height (cm) of common and dominant grass species found in the studied soil types

	Soil types			
Grass species	Hutton	Avalon	Clovelly	SEM
Aristida congesta	38.7[b]	49.0[a]	49.0[a]	3.2
Andropogon schirensis	25.7[a]	0.01[b]	0.01[b]	0.49
Cynodon dactylon	33.6[a]	33.2[a]	36.4[a]	4.1
Digitaria eriantha	26.0[b]	35.1[a]	27.6[b]	2
Eragrostis chloromelas	64.6[a]	25.1[c]	52.8[b]	2.5
Eragrostis curvula	42.8[a]	41.4[a]	44.1[a]	1.4
Eragrostis gammiflua	44.6[b]	41.0[b]	52.4[a]	1.2
Eragrostis micrantha	33.1[a]	0.01[b]	0.01[b]	0.6
Elionurus muticus	13.8[a]	0.01[b]	0.01[b]	0.76
Eragrostis racemose	25.1[a]	0.01[b]	0.01[b]	0.7
Eragrostis plana	46.3[a]	33.1[b]	48.4[a]	3.6
Eragrostis rigidior	14.3[a]	0.01[b]	0.01[b]	0.62
Heteropogon contortus	55.8[a]	0.01[b]	0.01[b]	3.2
Harpochloa falx	16.6[a]	0.01[b]	0.01[b]	0.79
Hyparrhenia hitra	0.01[b]	40.8[a]	0.01[b]	0.74
Paspalum dilatatum	28.4[a]	0.01[b]	25.9[a]	1.1
Stiburus alopecuriodes	38.6[a]	0.01[b]	0.01[b]	1.6
Setaria sphacelata	0.01[b]	0.01[b]	44.0[a]	0.68
Tristachya leucotrix	19.4[a]	0.01[b]	0.01[b]	0.49
Themeda triandra	52.1[a]	0.01[c]	30.3[b]	2.9
Urochloa paniciodes	28.4[a]	0*.01[b]	0.01[b]	0.79

[abc] Same lowercase superscript letters within the same row indicate a non-significant difference between the soil types (P>0.05).

SEM: Standard error of the mean.

3.3.6 Tuft diameter of common and dominant grass species

Tuft - a bunch of grass held together at the base. The tuft diameter of common and dominant grass species growing on the three soil types are presented in Table 3.8. *Cynodon dactylon* plants had greater ($P<0.05$) tuft (3.2 cm) diameter on Clovelly soil type when compared to the same species on other soil types.

Table 3.8: Tuft diameter (cm) for common and dominant grass growing in the studied soil types

Grass species	Soil type			SEM
	Hutton	Avalon	Clovelly	
Aristida congesta	1.9[b]	3.4[a]	2.2[b]	0.15
Andropogon schirensis	3.4[a]	0.01[b]	0.01[b]	0.09
Cynodon dactylon	2.6[b]	1.4[c]	3.2[a]	0.06
Digitaria eriantha	3.9[a]	3.2[b]	3.3[b]	0.13
Eragrostis chloromelas	4.4[a]	2.2[c]	3.3[b]	0.1
Eragrostis curvula	3.4[a]	3.3[a]	3.1[a]	0.11
Eragrostis gammiflua	3.2[a]	3.2[a]	3.1[a]	0.13
Eragrostis micrantha	3.3[a]	0.01[b]	0.01[b]	0.09
Elionurus muticus	4.0[a]	0.01[b]	0.01[b]	0.05
Eragrostis racemose	3.7[a]	0.01[b]	0.01[b]	0.09
Eragrostis plana	3.3[a]	3.3[a]	3.2[a]	0.07
Eragrostis rigidior	2.5[a]	0.01[b]	0.01[b]	0.05
Heteropogon contortus	3.3[a]	0.01[b]	0.01[b]	0.04
Harpochloa falx	3.3[a]	0.01[b]	0.01[b]	0.04
Hyparrhenia hitra	0.01[b]	3.5[a]	0.01[b]	0.08
Paspalum dilatatum	3.3[a]	0.01[b]	3.4[a]	0.08
Stiburus alopecuriodes	3.1[a]	0.01[b]	0.01[b]	0.08
Setaria sphacelata	0.01[b]	0.01[b]	3.3[a]	0.03
Tristachya leucotrix	3.5[a]	0.01[b]	0.01[b]	0.04
Themeda triandra	4.0[a]	0.01[c]	3.2[b]	0.06
Urochloa paniciodes	3.3[a]	0.01[b]	0.01[b]	0.05

[abc] Same lowercase superscript letters found within the same row indicate a non-significant difference between the soil types (P>0.05).
SEM: Standard error of the mean.

3.4 Discussion

3.4.1 Soil parameters

Soil parameters are considered to be important factors influencing plant growth and the availability of nutrients (Fatunbi & Dube (2008a). The results in Table 3.2 showed that selected communal rangelands were mostly composed of sandy soils and were found at 1000 m altitude. Avalon soil type had the highest pH value (4.5), compared to Hutton (3.5) and Clovelly (3.6) soil types which had lower pH values. These pH results indicate that these rangelands are facing a soil acidification problem since the best soil pH is considered to be in ranges 5.2-8.0. For most agricultural plants, including grasses, a low soil pH interferes with the uptake of beneficial elements such as P, Mg, and Ca due to reduced access to many grass species (Garrison, 2002). There was no variation in soil N-NHO_4 concentration in all the studied rangelands. However, Hutton soil type had the highest N-NO_3 concentration compared to Avalon and Clovelly soil types. Established plant communities are reported to be significantly affected by soil nitrogen (An *et al*., 2015). Lempesi *et al*. (2012) report that heavily grazed areas have a higher N concentration in their soil. A higher soil nitrogen concentration in soil under heavy grazing can be a result of ruminants' waste and urine when they are left to graze an area for a long period (Tamartash *et al*., 2007). Hutton and Clovelly soil types had higher organic carbon percentages than Avalon soil type. The soil's organic matter concentration is an important factor for soil health and productivity and is affected by grazing (Thomas, 2012; Liu *et al*., 1997). Micro and macro-minerals are vital for plant growth (Munshower, 1994). The selected communal areas were found to have high soil Ca, Mg, and K levels. According to Zhang *et al*. (2010), high concentrations of phosphate on soil surfaces instead of being in deep layers on flat landscapes with moderate slopes may be due to the formation of the crust on top of the soils. Factors such as reduced water, sand mobilization, dense grazing, and the deposition of nutrients are also reported to contribute to variations in nutrient availability and lead to the limited vegetation growth and these might also be associated to the obtained low soil nutrient values in this study (Goldberg, 1990).

3.4.2 Grass species composition and distribution

Data on the distribution of grass species is necessary to understand the flora biodiversity of the areas (An *et al*., 2015). Table 3.3 shows that the most abundant (90%) grass species life form was found to be tufted perennials while weak perennials (6.6%) and creeping grass (3%) life forms were less abundant. The availability of these perennial grass species can help in promoting organic carbon and soil health as well as a water-stable combination (Chan *et al*., 2001). The sandy soil type areas showed were covered with different species, but Increaser ii species were dominant with 42% coverage compared to other grass species. Tau (2005) stated that elevations between 1200 m and 1400 m tend to be dominated by **Increaser ii** species and that the increase of diverse Increaser ii species indicates long term overgrazing that may eliminate the preferred Decreaser species. The most dominant **Increaser ii** species were *Cynodon dactylon, E. chloromelas, E. curvula, E. plana,* and *E. rigidior* grass species. Their dominance as high palatable and moderately palatable grass species may result in a poor veld condition due to overgrazing by ruminants and Ravhuhali (2018) stated that species such as *Cynodon dactylon* is known as creeping grass that is unaccessible to the cattle. Veld managers must reduce the current spread of the above-mentioned species (Tau, 2005). From this study, the decreaser species had a coverage of 23% only, a higher percentage of **Decreaser** species will be beneficial for the survival of ruminants (Sisay & Baars, 2002). **Increaser iii**, climax grass, and exotic grass were found to cover about 3% of the soil types. **Increaser i** and other unspecified grass species were found to cover about 13 % of the soil types. Van Oudtshoorn (2014) emphasized that **Increaser i** to **Increaser iii** grass species are very common in under-grazed and over-grazed areas.

From the grazing values, the results from this study indicated that there was a high proportion of moderately palatable grass compared to highly palatable grass species. The presence of unpalatable species means a decrease in nutrient consumption by ruminants (Gusha & Mugabe, 2013), whereas the low value of high palatable grasses indicated that preferential grazing could be the prominent cause to the possible local extinction of desirable forage species. Gusha *et al*. (2017), stated that the reduction of desirable species may be due to frequent defoliation under continuous grazing.

3.4.3 Frequencies of occurrences for dominant and common grasses

Table 3.4 shows that *Digitaria eriantha*, *E. racemosa, H. contortus* and *T. triandra* grass species are dominant on Hutton soil type and showed a higher occurrence frequency than on other soil types. However, their dominance results in a poor veld condition (Tau, 2005). *Cynodon dactylon* and *E. chloromelas* grass species were dominant on Clovelly soil type thus showing a higher frequency of occurrence than on other soil types. Both these kinds of grass are increaser species, and may together contribute to the largest proportion of the total dry matter production available for the grazing ruminants (Kwaza, 2013).

3.4.4 The desirability of grass species

The palatability of grass species influences the response in terms of preference for grazers (CGIAR, 2009). The results from Table 3.5 indicate that all selected communal areas had the same amount of palatable and non-palatable grasses present on their soil types. Avalon soil type was found to have a higher frequency of moderately palatable grasses covering the area compared to Clovelly and Hutton soil types. According to van der Westhuizen *et al*. (2005), the over-estimation of the production potential in rangeland may lead to overgrazing and consequently cause a reduction of palatable perennial plants to favour the less or unpalatable and pioneer annual plants. Todd & Hoffman (1999) proposed that the decrease in desirable plant species resulted from preferential grazing. Gusha *et al*. (2017) mentioned that over-stocking is also a possible factor in lowering the proportion of desirable species in communal farming systems. Morris & Kotze (2006) found that palatable species in their study occurred naturally in well-managed rangelands compared to those found in poorly managed rangelands.

Digitaria eriantha, Aristida congesta, Eragrostis chloromelas, Eragrostis curvula, Eragrostis plana, and *Eragrostis gummiflua* were found to be commonly and dominantly distributed across all the soil types, these also indicate that there is a similarity in vegetation across the studied soil types and correlates the soil factors in terms of nutrition and organic matter. According to a study by Van der Westhuizen *et al*. (2005), *Aristida congesta, Eragrostis chloromelas, Eragrostis plana,* and *Eragrostis gummiflua* grass species may be used as dominant indicator species for rangeland condition. The dominance of *Eragrostis chloromelas* on Clovelly soil type indicates a moderate condition rating at 50% rangeland condition. The dominance of *Eragrostis chloromelas, Digitaria eriantha,* and *Eragrostis gummiflua* indicates a good-to-excellent condition for a rangeland.

3.4.5 Biomass production and grazing capacity

Plant cover is important as protection against soil erosion and weeds as well as a source of forage for livestock (Kioko *et al*., 2012). No significant difference was obtained in biomass production across all the selected communal grazing lands. Nevertheless, biomass yield tended to be lower on the Avalon soil type, which may be attributed to a heavier stocking rate. Additionally, domestic livestock grazing results in variations of plant species composition, which causes reduced grazing capacity (Dean & Macdonald, 1994, Wiegand *et al*., 1998).

Abusuwar & Ahmed (2010) proposed the practise of moderate grazing to maintain moderate plant growth. The biomass and diversity of high grazing value plants would decrease with increasing proximity to homesteads (Montague-Drake & Croft, 2004). Biomass potential may also be affected by grazing and climatic conditions. Angassa and Oba (2010) have reported that biomass production is affected during the wet seasons changing into dry seasons, consequently, biomass production is reduced in the dry season compared to the wet season which tends to be higher. Ecological changes may be studied through the botanical composition for the improvement of rangelands (Malan & Van Nierkerk, 2005). Maki *et al*. (2007) reported that changes in grazing pressure directly influence changes in vegetation structure, composition, and productivity.

3.4.6 Height of dominant and common grass species

There was no variation in terms of height for *A. congesta* grass species growing on Avalon and Clovelly soil types with a higher height compared to the same species growing on Hutton soil type. According to Gusha *et al*. (2017), this could be connected to continuous heavy grazing and also overstocking worsens through frequent defoliation of available desirable species, and thus affecting grass species height. There was a variation in height for the grass species *T. triandra* on Hutton soil type compared to other soil types, the presence of this palatable grass species will be beneficial for the survival of livestock (Tau, 2005). Differences in grass height may be influenced by growth rate or form, leaf to stem ration, and nutrient uptake, also due to palatability and grazing preferences by ruminants to some grasses living them to be grazed more than others and other unpalatable grasses left ungrazed (CGIAR, 2009).

3.4.7 Tuft diameter of dominant and common grass species

Table 3.8 showed that *Cynodon dactylon* had variation in diameter from all the grazing lands, and was most dominant on Clovelly soil type compared to the Avalon and Hutton soil types.

This grass species is considered to be highly palatable with a chemical composition of 9-16% protein, which aids with nutrition during grazing time (Matlebyane *et al*., 2010). *Eragrostis curvula* which is moderately palatable, *E. gummiflua* and *E. plana* which are non-palatable grass species showed no variation in diameter growing across all the selected communal areas. Trollope *et al*. (1990) and Hardy *et al*. (1999) stated that when spotting botanical composition, common or dominant with Increaser ii species, it usually represents that rangeland is in a poor veld condition, which could be the result of different factors involved such as rotational grazing and stocking rates. The current study reported variation in tuft diameter values, which could be due to the soil erosion due to sustained high grazing pressures in the communal areas.

3.5 Conclusion

Thirty-one grass species were found in the three studied communal rangeland soil types. All the studied soils were found to have an acidic pH concentration. The study areas were found to at least have one highly palatable grass species present. Hutton soil type contained the highest amount of palatable grass species as well as the least amount of unpalatable grass species. Although the communal study areas were not degraded, soil nutrient status such as carbon was lower in Avalon and Clovelly soil types. Results from this study have indicated some differences with the grass species composition, amount of desirable grass species, and the grass height between the studied communal rangelands. Though differences were not observed on grazing capacity in different soil types, Hutton soil type had a numerically higher grazing capacity when compared to other soil types. Due to the absence of enough rest leading to rangeland deterioration, forage plants need to recuperate from defoliation, therefore, recommending rotational grazing and resting systems to allow vegetation recovery can be of paramount importance in these communal areas.

3.6 References

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4 CHAPTER FOUR: CHEMICAL COMPOSITION AND SIMULATED RUMINAL FERMENTATION OF DOMINANT AND COMMON GRASS SPECIES FROM SELECTED COMMUNAL RANGELANDS IN MSUKALIGWA MUNICIPALITY

Abstract

The study was carried out to determine the effect of soil type on chemical composition and *in vitro* ruminal dry matter degradability (DMD) of dominant and common grass species from the three selected communal rangelands (Breyten (Hutton soil type), Davel (Avalon soil type) and Wesselton (Clovelly soil type)). The above-ground grass biomass was measured and harvested from transects at 20 m intervals using a falling plate meter (Disc Pasture Meter) and was dried in the oven at 60°C and further milled through a 2mm screen and stored awaiting for nutritional analyses. A two-way (grass species and soil type) analysis of variance in completely randomised designed (CRD) was used to statistically analyze the chemical composition and *in vitro* ruminal fermentation data. Dry matter, organic matter, nitrogen and fibre concentration were analysed. The *in vitro* ruminal DM degradability of dominant and common grass species samples was measured using the ANKOM Daisy^{II} incubator according to the ANKOM Technology Method number three (*in vitro* true digestibility). The results showed that *Eragrostis micrantha, H. hitra, E. racemosa,* and *S. sphacelata* had the same (P>0.05) neutral detergent fibre (NDF), acid detergent lignin (ADL), cellulose, and hemicellulose values. *Digitaria eriantha*, *E. plana*, and *E. gummiflua* on Hutton soil type had the highest (P<0.05) N content (17.0, 12.8 and 10.5 g/kg DM, respectively) when compared to the same species on other soil types. *Digitaria eriantha* on Hutton and Clovelly soil types had higher (P<0.05) Ca concentration (4.1 and 4.3 g/kg DM, respectively) when compared to all other species in the same soil types. *Eragrostis gummiflua* on Hutton and Avalon soil types had higher (P<0.05) Ca concentration (2.4 and 2.5 g/kg DM, respectively) when compared to the same species on Avalon soil type (1.5 g/kg DM). *Eragrostis* *chloromelas* on Hutton and Clovelly soil types also had higher (P<0.05) Fe concentration (259.2 and 186.3 g/kg DM, respectively) when compared to the same species on Avalon soil type. *Eragrostis chloromelas* on Hutton soil type had the same (P>0.05) ADL value as all other species from the same soil type. The results showed a higher N concentration of *T. triandra* species across all the soil types. For ruminal fermentation, all the species on Hutton soil type had the same (P>0.05) degradability values at 12 hours. There was a significant difference in grass species on DMD at 12, 24, 36, 48, and 72 hours of incubation. Grass species on Hutton and Avalon soil types had the same (P>0.05) degradability values at 24 hours. *Eragrostis chloromelas* on Clovelly soil type had the highest (P<0.05) 36 h DMD amount (649.3 g/kg DM) when compared to the same species in other soil types. The results imply that the soil type affected chemical composition values and DMD of dominant and common grass species. Due to the low N concentration of the grass species, supplementation will be required to meet daily livestock protein requirements on all the studied soil types. Further studies on assessing these species at different growth stages are required in the communal areas to improve communal livestock productivity.

Keywords: Dry matter degradability, forage quality, *in vitro* ruminal fermentation, macro and micro-minerals, nutritional value, soil type.

4.1 Introduction

Rangelands play a vital role in the economic development of rural communities through livestock production and are indispensable to the locals in a particular area (Palmer & Ainslie, 2007: Chiepe *et al*., 2017). The quality and quantity of the available forage in communal grazing lands largely influences the productivity of ruminants (Schlesinger, 1997; Little *et al*., 2015). According to Vallentine (1990), Berhane *et al*. (2006), and Woolley *et al*. (2009), livestock productivity highly depends on the quantity and quality of available forage. The grass quality involves nutrients and feeds digestibility, whereas the quantity is influenced by factors such as vegetation structure, access of water, soil composition and climate. The evaluation of livestock grazing capacity and nutritive value are the most important things to consider when doing forage quality and quantity assessment (Peden, 2005; Arzani & Naseri, 2007; Baumont *et al*., 2008). The determinants of forage quality include Acid Detergent Fibre (ADF), Metabolism Energy (ME), Neutral Detergent Fibre (NDF), and Crude Protein (CP) (Hoffman *et al*., 2001; Pinkerton, 2005). The determinants of plant species' nutritive value and digestibility are the grass species' stage of growth (Scurlock & Hall, 1998; Turk *et al*., 2007). The vegetation structure is determined by the soil composition and is directly associated with grazing, whereas the feed's nutrients are influenced by climate conditions and seasonal changes with an exception that other plants can preserve their nutrients after the reproductive stage (Fulkerson *et al*., 1998; Stockdale, 1999; Lesoli, 2011).

Some abiotic and biotic factors, together with anthropogenic factors, may be altered due to land management systems and thus influence the nutritional demands of the vegetation (McGranahan & Kirkman, 2013). Soil is essential for all plant growth (Rasaei *et al*., 2006; Li *et al*., 2007). The objective of this study was to determine the effect of soil type on chemical composition and *in vitro* ruminal dry matter degradability of grass species in Msukaligwa municipality. This would assist local managers or farmers to improve and optimize forage intake, forage nutritive concentration or deficiencies, supplementary strategies and more (CGIAR, 2009; Schut *et al*., 2010).

4.2 Materials and methods

4.2.1 Harvesting

Grass species were collected following the technique described in Chapter 3, Section 3.2.4. Before the *in vitro* ruminal fermentation and chemical composition analysis, the grass species samples were stored separately from each site. The samples were then dried for 24 hours in the oven at 60° C, then they were crushed and passed through a 2 mm sieve and stored in a plastic container until further use.

4.2.2 Chemical analysis

To determine dry matter (DM) 1 g of grass was weighed into a pre-weighed porcelain crucible and placed in an oven at 105° C for 12 hours. The DM was determined as the weight after oven drying. To determine organic matter (OM), the dried grass samples were further placed in an incinerator for 6 hours at 600° C to obtain ash (AOAC, 1990, method number 942.05). The total nitrogen concentration was determined through the Kjeldahl standard AOAC (1999, method number 984.13), the crude protein (CP) was obtained by multiplying the obtained nitrogen percentage with a factor of 6.25. The acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined by using the $ANKOM^{2000}$ fibre analyser (ANKOM Technology, New York), for 1 hour, 0.45 g of each grass sample was refluxed with acid and neutral detergent solution. Some α-amylase (from heat-stable bacteria) was used for NDF analysis. The dried ADF sample bags were soaked in a 72% H_2S0_4 solution to determine acid detergent lignin (ADL) (Van Soest *et al*., 1991).

4.2.3 Mineral analysis

The mineral concentration for the grass was determined at the Animal Health Centre Laboratory (North-West University) following the guidelines by the Agri-Laboratory Association of

Southern Africa (AgriLASA, 1998). The previously obtained DM samples (Section 4.2.2) were further incinerated for 12 hours in a muffle furnace. The remaining ash was measured and microwave-digested for 45 minutes with 10 mL of 32% hydrochloric acid and 1 mL of 55% nitric acid and, then left to cool at room temperature. The samples were transferred into 100 mL volumetric flasks and filled-up to the mark with distilled water and the deposits were allowed to settle for 24 hours, the top liquid was slowly poured into McCartney bottles without disturbing the lower residues to analyse the Mg, Na, Co, Mn, Si, Cu, K, S, Mo, Fe, P, Zn, and Ca concentrations available in the grass using the ICP Mass Spectrometer (PerkinElmer, NexION 300Q).

4.2.4 Ruminal fermentation

The ANKOM Daisy^{II} incubator (ANKOM Technology Corporation, Fairport, New York) was used to determine the *in vitro* ruminal dry matter degradability of the common and dominant grass species samples. About 0.45-0.5 g of the milled grass samples were weighed and transferred into 0.45-0.5g ANKOM F57 bags, the bags were sealed using a heat sealer and stored in daisy digestion jars including the control F57 bags without grass samples inside (blank bag correction factor). The daisy jars were further filled with 1600 mL of mixed buffer solution (RPT buffer) prepared at a ratio of 1:5 and kept warm. A Bonsmara cow was used as a source of rumen fluid containing natural inoculum, about 500 mL of the fluid was collected through the cannula in the morning before feeding and squeezed into pre-warmed thermos flasks, the top was flushed with carbon dioxide (CO_2) gas before closing the lid and immediately rushed to the lab, at the lab, the collected rumen fluid was processed in a blender and strained with a cheese cloth, each of the daisy jars was then inoculated with 10 mL of the filtered fluid and also flushed with CO_2 before incubation at 39° C in the ANKOM chamber. The jars were scheduled to stay at different times (12, 24, 36, 48, and 72 hours) of incubation. After the scheduled time, the F57 bags inside the daisy jars were removed from the incubator, washed with cold running water for about 20 minutes then dried in the oven for 12 hours at 105° C. The formula used to determine the *in vitro* dry matter degradability was:

$$\%IVTD\ (DM\ basis) = \frac{100 - \left(W3 - (W1\ x\ C1)\right)}{\text{W2 x DM}}\, x\ 100$$

Whereby; C1 = blank bag correction factor (final oven-dried weight ÷ original blank bag weight), DM = dry matter concentration, W1 = bag tare weight, W2 = sample weight, W3 = final bag weight after *in vitro* treatment.

4.2.5 Statistical analysis

The effect of plant species and soil type on chemical composition and the *in vitro* ruminal dry matter degradability were evaluated by the two-way analysis of variance (ANOVA). The means were separated using the probability of difference (PDIFF) option in the General Linear Model (GLM) procedure of SAS (2010) using the model:

$$Yij = \mu + Gi + Sj + (Gi\ x\ Si) + \varepsilon ij$$

Whereby; Y_{ij} = dependent variable, μ = overall mean, G_i = grass species effect, S_j = soil type effect, G_i x S_i = grass species and soil type interaction effect, ε_{ij} = random error

4.3 Results

4.3.1 Proximate composition of dominant and common grass species

Table 4.1 shows the results for statistical significance on the effect of soil type, grass species and their interaction on hemicellulose, cellulose, ADL, ADF, NDF, CP, ash, OM and DM of common and dominant grass species. Soil type was shown to have an influence ($P<0.05$, $P<0.001$) on DM and CP. Species had no significant ($P>0.05$) effect on DM and cellulose. Soil x grass species interaction had a significant effect on CP, ADF and cellulose and hemicellulose (P<0.05).

Table 4.1: Statistical significance on the effect of soil type, grass species and their interaction on hemicellulose, cellulose, ADL, ADF, NDF, CP, Ash, OM and DM (g/kg DM) of common and dominant grass species

	Factor		
Components[1] (g/kg DM)	**Soil type**	**Grass species**	**Soil x Grass species**
DM	*	NS	NS
OM	NS	**	NS
Ash	NS	**	NS
CP	**	**	**
NDF	NS	**	NS
ADF	NS	**	**
ADL	NS	**	NS
Cellulose	NS	NS	**
Hemicellulose	NS	*	*

NS = Non significance, * = P<0.05, ** = P<0.001.

[1]Components: DM = Dry matter, OM = Organic matter, CP = Crude protein, NDF = Neutral detergent fibre, ADF = Acid detergent fibre, ADL = Acid detergent lignin.

The DM, ash, OM and CP values of grass species found in three soil types are presented in Table 4.2. *Digitaria eriantha, E. chloromelas, E. curvula* and *E. gummiflua* had similar (P>0.05) DM values across the soil types. *Digitaria eriantha* on Hutton soil type had higher (P<0.05) ash (40.2 g/kg DM) when compared to other grass species from the same soil type. *Aristida congesta* on Hutton soil type had the same (P>0.05) ash value as *E. chloromelas, E. curvula*, *E. gummiflua* and *E. plana* from the same soil type. *Aristida congesta* on Avalon soil type had the same (P>0.05) ash value as *D. eriantha, E. chloromelas* and *E. plana* from the same soil type. *Digitaria eriantha* on Clovelly soil type had higher (P<0.05) ash (105.6 g/kg) value when compared to all other species from the same soil type. Within soil type, except for *A. congesta*, all species had the same (P>0.05) ash value on all soil types. *Aristida congesta* from Avalon soil type had a higher (P<0.05) ash value when compared to the same species on Hutton soil type (50.8 g/kg DM), whereas *A. congesta* on Clovelly soil type had the same (P>0.05) ash value as Hutton and Avalon soil types. *Aristida congesta* on Hutton soil type had the same (P>0.05) OM value as *E. chloromelas, E. curvula, E. gummiflua* and *E. plana* from the same soil type. *Aristida congesta* on Avalon, Hutton and Clovelly soil types showed to have the same (P>0.05) OM values.

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Table 4.2: Dry matter, ash, organic matter and crude protein content in common and dominant grass species growing in Hutton, Avalon and Clovelly soil types

	DM (g/kg)			Ash (g/kg DM)			OM (g/kg DM)			CP (g/kg DM)		
Grass species	HS	AS	CS	HS	AS	CS	HS	AS	CS	HS	AS	CS
Aristida congesta	941.6^{Bab}	958.7^{Aba}	969.3^{Aa}	50.8^{Bbc}	78.2^{Aab}	68.3^{ABb}	890.8^{Aab}	880.5^{Aab}	901.0^{Aab}	82.9^{Ab}	78.3^{Ab}	77.1^{Ab}
Digitaria eriantha	956.8^{Aa}	951.2^{Aab}	956.9^{Aa}	104.2^{Aa}	96.7^{Aa}	105.6^{Aa}	852.6^{Ac}	854.5^{Ab}	851.2^{Ac}	106.5^{Aa}	94.6^{Ba}	86.6^{Ba}
Eragrostis chloromelas	933.8^{Aab}	932.7^{Ab}	951.5^{Aa}	50.4^{Abc}	69.7^{Abc}	52.2^{Abc}	883.3^{ABb}	863.1^{Bb}	899.3^{Aab}	67.1^{Ac}	64.6^{Acd}	69.3^{Ab}
Eragrostis curvula	943.2^{Aab}	949.7^{Aab}	948.5^{Aa}	61.8^{Abc}	51.4^{Ac}	59.4^{Abc}	881.4^{Ab}	898.3^{Aa}	889.1^{Ab}	50.0^{Bd}	64.8^{Acd}	70.2^{Ab}
Eragrostis gummiflua	954.5^{Aa}	958.3^{Aa}	961.8^{Aa}	42.0^{Ac}	54.5^{Ac}	40.9^{Ac}	912.5^{Aa}	903.7^{Aa}	920.8^{Aa}	65.4^{Ac}	57.2^{Bd}	54.3^{Bc}
Eragrostis plana	927.6^{Bb}	951.1^{ABab}	952.5^{Aa}	62.9^{Ab}	71.7^{Abc}	59.6^{Abc}	864.8^{Bbc}	879.5^{ABab}	892.9^{Ab}	80.0^{Ab}	65.8^{Bc}	52.9^{Cc}
SEM		8.5			7.2			9.6			2.7	

^{ABC} Grass species means in the same row for each nutrient not sharing superscripts are significantly different ($P<0.05$).
^{abc} Soil type means in the same column not sharing superscripts are significantly different ($P<0.05$).
Soil types: HS = Hutton soil type, AS = Avalon soil type, CS = Clovelly soil type.
DM = Dry matter, Ash = Ash, OM = Organic matter, CP = Crude protein.
SEM: Standard error of the mean.

On all soil types, *Digitaria eriantha* had the highest (P<0.05) CP (106.5 g/kg DM) content when compared to all other. The lowest CP content was observed on *E. chloromelas* (67.1 g/kg DM) and *E. gummiflua* (65.4 g/kg DM) on Hutton soil type than other grass species in the same soil type. *Eragrostis chloromelas* on Avalon soil type had similar (P>0.05) CP value as *E curvula*, *E. gummiflua* and *E. plana* concentration. The least (P<0.05) CP values were observed in *Eragrostis gummiflua* (54.3 g/kg DM) and *E. curvula* (52.9 g/kg DM) on Clovelly soil type in comparison to all other species found on the same soil type. *Aristida congesta* and *E. chloromelas* had the same (P>0.05) CP values on all soil types. *Digitaria eriantha* and *E. gummiflua* Hutton soil type had the highest (P<0.05) crude protein content (106.5 g/kg DM and 65.4 g/kg DM) than the same species on Avalon and Clovelly that were not significantly (P>0.05) different from each other on their respective soil types. *Eragrostis curvula* on Avalon (64.8 g/kg DM) and Clovelly (70.2 g/kg DM) soil types had the highest (P<0.05) crude protein values in comparison to the same species on Hutton soil type. The *E. plana* on Hutton soil type had higher (P<0.05) CP (80.0 g/kg DM) concentration when compared to Avalon and Clovelly soil types which also differed (P<0.05) significantly from each other (65.8 g/kg DM and 52.9 g/kg DM).

4.3.2 Fibre concentration

The effects of grass species and soil type on NDF, ADF, ADL, cellulose and hemicellulose of common and dominant grass species growing on the different selected rangelands are presented in Table 4.3. *Aristida congesta, D. eriantha, E. chloromelas, E. curvula, E. gummiflua* and *E. plana* on Avalon soil type had similar (P>0.05) NDF concentration values. *Digitaria eriantha* showed to have the lowest (P<0.05) NDF (696.4 g/kg DM) value than other grass species growing on the same Avalon soil type. *Aristida congesta* on Hutton soil type had higher (P<0.05) ADF (714.9 g/kg DM) value compared to other species from the same soil type. *Digitaria eriantha* on Hutton soil type had the same (P>0.05) ADF content as *E. chloromelas, E. curvula, E. gummiflua* and *E. plana* from the same soil type. *Eragrostis gummiflua* on Avalon soil type had similar (P>0.05) ADF value as all other grass species from the same soil type. *Eragrostis chloromelas* on Clovelly soil type had the same (P>0.05) ADF value as all other species from the same soil type. Within soil type, *D. eriantha, E. curvula* and *E. plana* had the same (P>0.05) ADF concentration across all the three soil types. *Aristida congesta* on Hutton soil had a higher ADF (714.9 g/kg DM) value than the same grass species on Avalon (576.3 kg/kg DM) and Clovelly (461.3 g/kg DM) soil types. *Eragrostis chloromelas* on Avalon soil type had the highest (P<0.05) ADF (588.9 g/kg DM) concentration when compared to the same species on other soil types which did not differ from each other. *Eragrostis gummiflua* on Avalon (514.5 g/kg DM) and Clovelly (525.4 g/kg DM) soil types had higher (P<0.05) ADF values when compared to the same grass species on Hutton soil type. *Eragrostis chloromelas* had the same (P>0.05) ADL value as *A. congesta* and *E. plana s*pecies on Avalon soil type. *Eragrostis plana* on Avalon soil type had the same (P> 0.05) ADL content as *E. gummiflua, E. curvula,* E. *chloromelas* and *D. eriantha*. *Aristida congesta, D. eriantha*, *E. curvula, E. gummiflua* and *E. plana* had the same (P>0.05) ADF values across all three soil types. *Eragrostis chloromelas* on Avalon soil type had a higher (P<0.05) ADL (189.3 g/kg DM) value than the same grass species on other soil types.

Table 4.3: Effect of soil type and grass species on cell wall composition (g/kg DM) of common and dominant grass species in selected communal areas concentration

	Fibre[1]														
	NDF			ADF			ADL			Cellulose			Hemicellulose		
Grass species	HS	AS	CS	HS	AS	CS	HS	AS	CS	HS	AS	CS	HS	AS	CS
A. congesta	779.8^{Aab}	814.9^{Aa}	763.9^{Aab}	714.9^{Aa}	576.3^{Ba}	461.3^{Cab}	174.0^{Aa}	220.4^{Aa}	179.2^{Aa}	540.9^{Aa}	355.9^{Ba}	282.1^{Bb}	64.9^{Bd}	238.6^{Aab}	302.6^{Aa}
D. eriantha	688.2^{Ac}	696.4^{Ab}	684.7^{Ac}	427.7^{Abc}	436.1^{Ab}	392.4^{Ab}	109.5^{Ab}	116.9^{Ac}	86.6^{Ab}	318.1^{Ab}	319.2^{Aa}	305.8^{Aab}	260.5^{Abc}	260.3^{Aab}	292.3^{Aa}
E. chloromelas	715.7^{Ac}	764.1^{Aa}	732.1^{Abc}	400.2^{Bc}	588.9^{Aa}	467.7^{Bab}	111.6^{Bab}	189.3^{Aab}	115.9^{Bab}	288.6^{Bb}	399.6^{Aa}	351.8^{ABab}	315.5^{Aabc}	175.2^{Bb}	264.4^{ABa}
E. curvula	813.0^{Aa}	810.2^{Aa}	806.5^{Aa}	444.5^{Abc}	461.6^{Ab}	502.0^{Aa}	129.4^{Aab}	91.3^{Ac}	130.7^{Aab}	315.1^{Ab}	370.3^{Aa}	371.4^{Aab}	368.5^{Aab}	348.6^{Aa}	304.4^{Aa}
E. gammiflua	774.0^{Aabc}	781.8^{Aa}	802.8^{Aa}	362.9^{Bc}	514.5^{Aab}	525.4^{Aa}	73.9^{Ab}	103.7^{Ac}	115.6^{Aab}	288.9^{Bb}	410.8^{Aa}	409.8^{Aa}	411.1^{Aa}	267.4^{Bab}	277.3^{Ba}
E. plana	728.1^{Bbc}	771.9^{ABa}	801.6^{Aa}	508.0^{Ab}	448.6^{Ab}	477.5^{Aab}	117.1^{Aab}	127.0^{Abc}	109.7^{Ab}	390.9^{Ab}	321.6^{Aa}	365.8^{Aab}	220.2^{Ac}	323.2^{Aa}	326.1^{Aa}
SEM		20.6			34.3			22.3			38.0			40.6	

^{ABC} Grass species means in the same row for each nutrient that do not share superscripts are significantly different (P<0.05).

^{abc} Soil type means in the same column that do not share superscripts are significantly different (P<0.05).

[1]Fibre: NDF = Neutral detergent fibre, ADF = Acid detergent fibre, ADL = Acid detergent lignin.

Soil types: HS = Hutton soil type, AS = Avalon soil type, CS = Clovelly soil type.

SEM: Standard error of the mean.

Aristida congesta on Hutton soil type had higher (P<0.05) cellulose concentration (540.9 g/kg DM) when compared to other species from the same soil type. *D. eriantha, E. curvula,* and *E. plana* had the same (P>0.05) cellulose content across all three soil types. *Aristida congesta* on Hutton soil type had higher (P<0.05) cellulose concentration (540.9 g/kg DM) when compared to the same species on other soil types. *Eragrostis gummiflua* on Avalon (410.8 g/kg DM) and Clovelly (409.8 g/kg DM) soil types had the highest (P<0.05) cellulose values (410.8 g/kg DM and 409.8 g/kg DM) than the same grass species growing on Hutton soil type (288.9 g/kg DM). All species on Clovelly soil type had the same (P>0.05) hemicellulose content. *D. eriantha, E. curvula,* and *E. plana* had the same (P>0.05) hemicellulose content across all three soil types. *Eragrostis chloromelas* and *E. gummiflua* on Hutton soil type had higher (P<0.05) hemicellulose content (315.5 g/kg DM and 411.1 g/kg DM) when compared to the other soil types. *Aristida congesta* on Avalon and Clovelly soil types had a higher (P<0.05) cellulose concentration (238.6 g/kg DM and 302 g/kg DM) 540.9 g/kg DM) than the same grass species from Hutton soil type (64.9 g/kg DM).

4.3.3 Minerals

Results for the statistical significance (P-value) of the effect of soil type, grass species and their interaction on macro/micro-mineral elements in common and dominant grass species growing on the selected rangeland sites are presented in Table 4.4. The significant (P<0.05) effect of soil, grass species and grass x soil type interaction were observed on N, P, Mg, Na, Zn, Cu, Co and Mo concentration. However, soil type did not affect Si, Fe, Ca, and S content.

Table 4.4: Statistical significance of the effect of soil, grass species, and soil × grass species interaction on the macro and micro-mineral elements of grass species

	Factor		
Mineral	Soil	Grass species	Soil × grass species
N	*	**	**
P	**	**	**
Mg	**	**	**
Ca	NS	**	*
S	NS	**	*
Na	**	**	**
Si	NS	**	*
Fe	NS	**	**
Mn	**	**	**
Zn	**	**	**
Cu	**	**	**
Co	*	**	**
Mo	**	**	**

NS = Not significant, * = P<0.05, ** = P<0.001.

4.3.3.1 Macro minerals

Macro mineral (Ca, P, S, Na, and Mg) concentration of dominant and common grass species found in selected communal sites are presented in Table 4.5. *Digitaria eriantha* on Hutton and Clovelly soil types had higher (P<0.05) Ca concentration than all other grass species. In All soil types, *D. eriantha* had higher (P<0.05) than the other grass species. *Eragrostis chloromelas* on Hutton soil type had the same (P>0.05) S value as *Digitaria eriantha, E. curvula* and *E. plana*. On Avalon and Clovelly soil types, *Eragrostis curvula* (2.3 and 2.4 g/kg DM) had higher (P<0.05) S concentration in comparison to the same grass species on Hutton soil type (2.2 g/kg DM). *Aristida congesta* (2.6 g/kg DM) on Avalon soil type had higher (P<0.05) S concentration than the same grass species growing on Hutton and Clovelly soil types (0.889 and 1.7 g/kg DM). *Digitaria eriantha* on Hutton and Avalon soil types had the highest ($P<0.05$) sodium concentration when compared to the other grass species. On Clovelly soil type, *Eragrostis gummiflua* had the highest (0.077 g/kg DM) Na content when compared to all other species on the same soil type. *Aristida congesta* (0.025 and 0.033 g/kg DM) on Avalon and Clovelly soil types had higher ($P<0.05$) Na content when compared to the same species on Hutton soil type. *Digitaria eriantha* on all soil types had higher ($P<0.05$) Mg (0.455 g/kg DM) than all other species. *Eragrostis curvula* (0.145 g/kg DM) on Hutton soil type had higher ($P<0.05$) Mg than the same species on Clovelly and Avalon soil types (0.080 and 0.070 g/kg DM).

Table 4.5: Macro-mineral constituents (mg/g DM) of common and dominant grass species obtained from the selected sites

	Ca			**P**			**S**			**Na**			**Mg**		
Grass species	HS	AS	CS	HS	AS	CS	HS	AS	CS	HS	AS	CS	HS	AS	CS
Aristida congesta	2.3^{Ab}	1.6^{Bd}	2.2^{ABbc}	0.08^{Bc}	0.12^{Ad}	0.094^{Bb}	0.889^{Bd}	2.6^{Aab}	1.7^{Bbc}	0.013^{Bc}	0.025^{Acd}	0.033^{Ac}	0.097^{Ab}	0.070^{Ab}	0.081^{Ab}
Digitaria eriantha	4.1^{Aa}	3.2^{Ba}	4.3^{Aa}	0.365^{Ba}	0.563^{Aa}	0.359^{Ba}	3.4^{Aa}	3.2^{Aa}	2.3^{Aab}	0.040^{Ba}	0.095^{Aa}	0.012^{Ce}	0.455^{Ba}	0.750^{Aa}	0.423^{Ba}
Eragrostis chloromelas	2.5^{ABb}	2.8^{Aab}	1.9^{Bcd}	0.124^{Bb}	0.173^{Abc}	0.093^{Bb}	2.7^{Aab}	2.7^{Aab}	2.6^{Aa}	0.019^{Bbc}	0.022^{Bcd}	0.045^{Ab}	0.124^{Ab}	0.097^{Ab}	0.089^{Ab}
Eragrostis curvula	2.5^{Ab}	2.3^{ABc}	1.7^{Bcd}	0.141^{Bb}	0.187^{Ab}	0.076^{Cb}	$2.\ 2^{Bbc}$	$2.\ 3^{Ab}$	2.4^{Aab}	0.022^{Abc}	0.018^{Ad}	0.019^{Ade}	0.145^{Ab}	0.080^{Bb}	0.071^{Cb}
Eragrostis. gammiflua	2.4^{Ab}	2.5^{Abc}	1.5^{Bd}	0.083^{Ac}	0.103^{Ad}	0.097^{Ab}	1.8^{Ac}	1.4^{Ac}	1.6^{Ac}	0.028^{Bb}	0.032^{Bc}	0.077^{Aa}	0.104^{Ab}	0.065^{Ab}	0.076^{Ab}
Eragrostis plana	2.3^{Bb}	2.9^{Aab}	2.5^{ABb}	0.072^{Bc}	0.136^{Acd}	0.091^{Bb}	2.3^{Abc}	1.00^{Bc}	1.8^{Aabc}	0.027^{Bb}	0.048^{Ab}	0.028^{Bcd}	0.103^{Ab}	0.089^{Ab}	0.079^{Ab}
SE		0.204			0.014			0.277			0.004			0.014	

^{ABC} Grass species means in the same row for each nutrient that do not share superscripts are significantly different ($P<0.05$).
^{abc} Soil type means in the same column that do not share superscripts are significantly different ($P<0.05$).
Soil types: HS = Hutton soil type, AS = Avalon soil type, CS = Clovelly soil type.
SEM: Standard error of the mean.

4.3.3.2 Micro minerals

The result of the grass species and soil type effect on trace elements of common and dominant species at different soil types are presented in Tables 4.6 and 4.7. With the exception of *E. gummiflua,* all grass species across all soil types had similar ($P>0.05$) Si concentration values. *Digitaria eriantha* on Hutton soil type had the same ($P>0.05$) Fe value as *E. chloromelas* and *E. curvula*. *Eragrostis chloromelas* and *E. plana* from Avalon soil type had the least ($P<0.05$) Fe values (25.3 and 50.0 g/kg DM). *Eragrostis gummiflua* (304.8 g/kg DM) and *Digitaria eriantha* (314.1 g/kg DM) on Clovelly soil type had the highest ($P<0.05$) Fe concentration when compared to other grass species from the same soil type. *Eragrostis plana* on Clovelly soil type had lower ($P<0.05$) Fe value (83.9 g/kg DM) than all other species from the same soil type. *Aristida congesta* on Avalon soil type had higher ($P<0.05$) Zn concentration (3.4 g/kg DM) than all other species from the same soil type. On Clovelly soil type, the highest ($P<0.05$) Zn concentration was obtained on *A. congesta* and *D. eriantha* (3.4 and 3.3 g/kg DM) than on all other species. *Aristida congesta* on Avalon and Clovelly soil type had the highest ($p<0.05$) Zn when compared to the same species on Hutton soil type. *Digitaria eriantha* on Clovelly soil type had the highest ($P<0.05$) Zn (3.3 g/kg DM) when compared to the same species on Hutton and Avalon soil.

Aristida congesta, D. eriantha, E. chloromelas and *E. curvula* on Hutton soil type had higher ($P<0.05$) Cu content when compared to *E. gummiflua* and *E. plana* on the same soil type which did not differ. On Avalon soil, *A. congesta* and *D. eriantha* had higher ($P<0.05$) Cu (3.9 and 4.4 g/kg DM) when compared to all other grass species on the same soil type. *Aristida congesta* on Clovelly soil type had the same ($P>0.05$) Cu value as *D. eriantha* and *E. plana* from the same soil type.

Table 4.6: Micro-elements (Si, Fe, Mn, Zn) (g/kg DM) of dominant and common grass species found in the selected sites

	Si			**Fe**			**Mn**			**Zn**		
Grass species	HS	AS	CS	HS	AS	CS	HS	AS	CS	HS	AS	CS
Aristida congesta	17.8^{Aa}	40.2^{Aa}	35.6^{Aa}	77.7^{Cd}	600.4^{Aa}	216.4^{Bb}	47.4^{Cbc}	566.1^{Aa}	479.5^{Ba}	0.654^{Bc}	3.4^{Aa}	3.4^{Aa}
Digitaria eriantha	53.4^{Aa}	33.4^{Aa}	53.8^{Aa}	275.9^{ABab}	205.9^{Bbc}	314.1^{Aa}	42.43^{Bc}	31.7^{Bc}	135.4^{Ab}	2.1^{Ba}	2.0^{Bc}	3.3^{Aa}
Eragrostis chloromelas	42.3^{Aa}	53.1^{Aa}	40.1^{Aa}	259.2^{Abc}	25.3^{Bd}	186.3^{Ab}	40.04^{Ac}	34.4^{Ac}	68.2^{Ac}	2.0^{Aa}	2.8^{Ab}	1.1^{Bd}
Eragrostis curvula	37.1^{Aa}	54.2^{Aa}	27.8^{Aa}	356.5^{Aa}	137.4^{Bc}	187.9^{Bb}	101.7^{Aab}	71.1^{Ac}	45.5^{Ac}	2.3^{Aa}	2.6^{Ac}	1.54^{Bbc}
Eragrostis gammiflua	27.8^{Aa}	30.5^{Aa}	24.7^{Bb}	194.5^{Bc}	269.3^{ABb}	304.8^{Aa}	121.9^{Ba}	309.5^{Ab}	97.7^{Bbc}	0.913^{Cbc}	1.5^{Bd}	1.9^{Ab}
Eragrostis plana	33.4^{Aa}	14.6^{Aa}	28.5^{Aa}	87.3^{Ad}	50.0^{Ad}	83.9^{Ac}	128.9^{Aa}	53.6^{Bc}	72.4^{ABc}	1.2^{Ab}	1.3^{Ad}	1.52^{Ac}
SEM		25.7			28.4			19.8			0.150	

^{ABC} Grass species means in the same row not sharing the common superscripts are significantly different (P<0.05).

^{abc} Soil type means in the same column not sharing the common superscripts are significantly different (P<0.05).

Soil types: HS = Hutton soil type, AS = Avalon soil type, CS = Clovelly soil type.

SEM: Standard error of the mean.

Table 4.7: Micro-elements (Cu, Co, Mo) (g/kg DM) in common and dominant grass species

	Cu			**Co**			**Mo**		
	HS	AS	CS	HS	AS	CS	HS	AS	CS
Aristida congesta	2.1^{Ba}	3.9^{Aa}	3.5^{Aba}	0.473^{Bd}	4.5^{Aa}	0.616^{Be}	0.020^{Cbc}	0.283^{Ab}	0.142^{Ba}
Digitaria eriantha	2.5^{Ca}	4.4^{Aa}	3.5^{Ba}	2.5^{Ab}	1.4^{Bc}	2.8^{Ab}	0.185^{Ba}	0.333^{Aa}	0.028^{Cc}
Eragrostis chloromelas	2.0^{Aa}	2.4^{Abc}	0.9^{Bd}	2.3^{Ab}	0.110^{Ce}	1.2^{Bd}	0.069^{ABb}	0.011^{Bd}	0.098^{Ab}
Eragrostis curvula	2.4^{Aa}	2.9^{Ab}	1.4^{Bcd}	2.9^{Aa}	0.846^{Cd}	1.7^{Bc}	0.046^{Bbc}	0.118^{Ac}	0.040^{Bc}
Eragrostis gammiflua	1.4^{Cb}	2.6^{Ab}	1.9^{Bc}	1.6^{Cc}	1.9^{Bb}	3.9^{Aa}	0.051^{Bbc}	0.042^{Cd}	0.176^{Aa}
Eragrostis plana	1.0^{Cb}	1.9^{Bc}	2.9^{Ab}	0.349^{Ad}	0.242^{Ae}	0.459^{Ae}	0.012^{Bc}	0.099^{Ac}	0.077^{ABb}
SEM		0.180			0.107			0.014	

^{ABC} Grass species means in the same row not sharing the common superscripts are significantly different (P<0.05).
^{abc} Soil type means in the same column not sharing the common superscripts are significantly different (P<0.05).
Soil types: HS = Hutton soil type, AS = Avalon soil type, CS = Clovelly soil type.
SEM: Standard error of the mean.

On Hutton soil, *E. curvula* (2.9 g/kg DM) had the highest (P<0.05) Co value while *A. congesta* and *E. plana* had the least values (0.473 and 0.349 g/kg DM). *Aristida congesta* (4.5 g/kg DM) on Avalon soil type had higher (P<0.05) Co concentration while on Clovelly soil, *E. plana* (3.9 g/kg DM) had higher (P<0.05) Co content when compared to the other grass species on the same soil types. On both Hutton and Avalon soil types, *D. eriantha* (0.185 and 0.333 g/kg DM) had the highest (P<0.05) Mo concentration. On Clovelly soil type, *A. congesta* and *E. gummiflua* had the highest (P<0.05) Mo content (0.142 and 0.077 g/kg DM).

4.3.4 In-vitro ruminal DM degradability

The results on the statistical significance of the effect of soil type, grass species and soil x grass species interaction factors on *in vitro* ruminal dry matter degradability (DMD12, DMD24, DMD36, DMD48 and DMD72) from common and dominant grass species on the selected rangeland sites are presented in Table 4.8.

Table 4.8: Statistical significance for the effect of the soil type, grass species and soil x grass species interaction effects on *in vitro* ruminal dry matter degradability of common and dominant grass species found in selected sites**.**

	Degradability[1]				
Factor	**DMD12**	**DMD24**	**DMD36**	**DMD48**	**DMD72**
Soil	NS	*	*	NS	NS
Grass species	*	*	**	*	*
Soil × grass species	NS	NS	*	NS	NS

NS =Not significance, * = P<0.05, ** = P<0.001.

[1]Degradability: DMD12 = Dry matter degradability at 12 hours, DMD24 = Dry matter degradability at 24 hours, DMD36 = Dry matter degradability at 36 hours, DMD48 = Dry matter degradability at 48 hours, DMD72 = Dry matter degradability at 72 hours.

The significant (P<0.05) effect of soil on DMD was observed in DMD12 and DMD36.

There was a significant (P<0.05) effect of grass species on DMD12, DMD24, DMD36, DMD48 and DMD72. A significant soil* grass species interaction effect was observed on DMD36 only.

The results on *in vitro* ruminal DM degradability values for the common and dominant grass species found on selected rangeland sites are presented in Table 4.9. All the species on the Hutton soil type had similar (P>0.05) DMD values at 12 hours. *Aristida congesta, E. curvula, E. gummiflua* and *E. plana* had similar (P>0.05) DMD values after 12 hours of incubation across all soil types. Hutton and Avalon soil type species had the same (P>0.05) *in vitro* degradability values at 24 hours. All grass species had similar DMD24 values, except *E. chloromelas* grass species.

On Avalon soil, the highest (P<0.05) DMD36 value was obtained in *E. chloromelas* (334.5 g/kg DM) while the least (P<0.05) DMD36 value was obtained in *E. plana* (158.9 g/kg DM). *Aristida congesta* growing on Avalon soil type had the same (P>0.05) 36-hour DMD value as *D. eriantha, E. chloromelas, E. curvula* and *E. gammiflua* from the same soil type. In Clovelly soil type, the highest (P<0.05) DMD36 value (649.3 g/kg DM) was obtained in *E. chloromelas* while the lowest value (229.1 g/kg DM) was found in *A. congesta*. Across all the selected soil types, *D. eriantha, A. congesta, E. curvula, E. gummiflua* and *E. plana* had the same (P>0.05) 48-hour DMD values. *Aristida congesta, D. eriantha, E. curvula, E. gummiflua* and *E. plana* had the same DMD72 values across all soil types.

Table 4.9: The effect of soil types and grass species on *in vitro* ruminal DMD degradability (g/kg) of common and dominant grass species from selected soil types

	DMD12			DMD24			DMD36			DMD48			DMD72		
Grass species	**HS**	**AS**	**CS**	**HS**	**AS**	**CS**	**HS**	**AS**	**CS**	**HS**	**AS**	**CS**	**HS**	**AS**	**CS**
A. congesta	67.4^{Aa}	102.1^{Ab}	121.1^{Ab}	152.5^{Aa}	175.5^{Aa}	169.6^{Ab}	194.7^{Ab}	253.9^{Aabc}	229.1^{Ac}	238.5^{Aa}	328.7^{Aab}	264.6^{Ab}	307.0^{Aa}	352.5^{Aab}	299.0^{Ac}
D. eriantha	105.3^{Ba}	185.7^{Aba}	202.1^{Aa}	205.1^{Aa}	252.2^{Aa}	327.6^{Ab}	288.0^{Aab}	293.8^{Aab}	381.0^{Ab}	320.4^{Aa}	390.9^{Aa}	409.4^{Ab}	416.7^{Aa}	472.2^{Aa}	507.3^{Aab}
E. chloromelas	98.8^{Ba}	176.0^{Aa}	95.9^{Bb}	158.5^{Ca}	253.0^{Ba}	537.0^{Aa}	229.6^{Cab}	334.5^{Ba}	649.3^{Aa}	289.8^{Ba}	373.8^{Bab}	623.6^{Aa}	411.6^{Ba}	446.3^{Bab}	681.0^{Aa}
E. curvula	116.7^{Aa}	85.2^{Ab}	112.5^{Ab}	164.5^{Aa}	107.0^{Aa}	211.4^{Ab}	196.6^{Ab}	168.4^{Abc}	256.3^{Abc}	245.1^{Aa}	248.4^{Aab}	287.2^{Ab}	304.7^{Aa}	401.5^{Aab}	327.7^{Ac}
E. gammiflua	122.7^{Aa}	77.0^{Ab}	112.8^{Ab}	193.0^{Aa}	140.6^{Aa}	206.5^{Ab}	331.5^{Aa}	179.7^{Bbc}	252.6^{ABbc}	395.3^{Aa}	231.0^{Aab}	281.9^{Ab}	429.4^{Aa}	293.7^{Ab}	358.2^{Abc}
E. plana	105.0^{Aa}	75.2^{Ab}	130.7^{Ab}	123.0^{Aa}	124.1^{Aa}	209.1^{Ab}	182.0^{Ab}	158.9^{Ac}	289.1^{Abc}	241.7^{Aa}	207.6^{Ab}	364.6^{Ab}	306.3^{Aa}	320.2^{Aab}	384.8^{Abc}
SEM		22.6			56.2			45.6			60.7			61.0	

^{ABC} Grass species means in the same row that do not share superscripts are significantly different (P<0.05).

^{abc} Soil type means in the same column that do not share superscripts are significantly different (P<0.05).

Soil types: HS = Hutton soil type, AS = Avalon soil type, CS = Clovelly soil type.

Degradability: DMD12 = Dry matter degradability at 12 hours, DMD24 = Dry matter degradability at 24 hours, DMD36 = Dry matter degradability at 36 hours, DMD48 = Dry matter degradability at 48 hours, DMD72 = Dry matter degradability at 72 hours.

SEM: Standard error of the mean.

4.4 Discussion

4.4.1 Proximate composition of grass species

There was no variation in terms of fibre concentration of grass species, which is different from the report of Ravhuhali (2018) who found wide variations in the fibre concentrations of species. *Eragrostis plana*, *A. congesta*, *D. eriantha*, *E. chloromelas*, *E. curvula*, and *E. gummiflua* grass species growing across all the soil types had similar DM and OM values above (800 g/kg), these findings concur with the results reported by Ravhuhali (2018) which showed an OM values above 800 g/kg. Hart & Leibholz (1990) stated that the stage of maturity for the plants influences cell wall composition and CP concentration. The highest CP across soil types was found in *D. eriantha* (86.6-106.5 g/kg) suggesting the genetic superiority of this species. However, the level of CP in this grass species was not adequate to meet the recommended levels of CP (70 g/kg DM) for maintenance of rumen function (Paterson *et al*., 1996: Gizachew & Smit, 2012). The ruminant diet is dependent on fibre to stimulate optimum rumen function but when lignified, especially when plants are harvested at maturity, the fibre is not easily digestible (Mlay *et al*., 2006). Indeed, grasses harvested at maturity tend to have higher fibre and lignin content compared to when harvested at early growing phases (Manyedi *et al*., 2017). *Aristida congesta, D. eriantha, E. chloromelas, E. curvula, E. gummiflua,* and *E. plana* had NDF levels ranging (660.0-835.7 g/kg DM) and ADF range (386.3-593.0 g/kg), which were opposite to the findings by Kwaza (2013). There were no distinct variations in the level of NDF and ADF values between selected dominant and common grass species across soil types, some of these findings were similar to the report of Kwaza (2013), the author found that the NDF and ADF concentrations in *E. chloromelas* and *E. plana* were ranging from (67.8-68.4%) and (33.7-41.3%), respectively. The reports from Heuzé *et al*. (2015) indicated that the NDF and ADF content of *D. eriantha* and *E. curvula* ranged from 64.7-82.7% and 29.2-47.3%, respectively.

This study concurs with the findings of Mahala *et al*. (2009) who reported that when there are higher NDF and ADF values, CP content tends to be lower. Higher values of fibre concentration and lower CP values indicated that the studied grass species would be difficult to digest when ingested by herbivores (Nsinamwa *et al*., 2005).

4.4.2 Minerals

The significant effects of soil type on Si, Fe, Ca, and S concentration values of grasses from this study are in line with those reported by Kwaza *et al*. (2016). Macro and micro-minerals availability for livestock consumption are important to maintain animal health and productivity during grazing (FAO, 2011; Rust & Rust, 2013). Differences in macro elements among the grass species within each soil type were similar to those reported by Campos *et al* (2010), and these differences reflect changes that occur in soil fertility status and seasonal variations influencing growth rate (Zafar *et al*., 2007). *Aristida congesta, D. eriantha, E. chloromelas, E. curvula, E. gummiflua,* and *E. plana* had Fe level in the range 50.0-600.4 g/kg DM, Cu level range 0.9-4.4 g/kg DM, and Zn level range 0.654-3.4 g/kg DM, which was extremely beyond the minimum requirement as advised by NRC (National Research Council) (1997) and McDowell (1997). AFZ (2011) also reported above critical levels of Fe and Zn than the normal ruminant requirements. These findings for most grass species have minerals either within or above the dietary requirement for livestock. It is also reported that the availability of minerals in soil tends to influence the mineral content of the grass (Horn, 2017). *Aristida congesta, E. curvula,* and *E. gummiflua,* had Ca levels ranging from 1.5 to 1.7 g/kg DM, and these values are below the recommended rate outlined by NRC (1996) and Mcdowell (1997) for ruminants, while *D. eriantha*, *E. chloromelas,* and *E. plana* had Ca levels ranging from 1.9 to 4.3 g/kg DM that fell within the standard requirements for ruminants. *Aristida congesta, D. eriantha, E. chloromelas, E. curvula, E. gummiflua,* and *E. plana* had Mg content ranging between 0.065-0.455 g/kg DM) and P content ranging between 0.072-0.563 g/kg DM which were below the required level for ruminant for P (1.2-4.8 g/kg DM) and Mg (1-2.5 g/kg DM) (National Research Council, 1996; McDowell, 1997). Berhane *et al*. (2006) also reported similar results and suggested that the low values of P and Mg could be caused by the soil being deficient in these minerals. The results from Table 4.4 showed a two way interaction which could be due to the nutrient availability in soil and the plant palatability.

4.4.3 In vitro ruminal degradability

There was little variation in the degradability values of *A. congesta, D. eriantha, E. chloromelas, E. curvula, E. gummiflua,* and *E. plana* grass species. Most grasses were poorly degraded. Yayneshet *et al*. (2009) report that grass species with low degradability are characterised by lower energy and nitrogen content and a higher fibre concentration. Such grasses do not promote optimal microbial biomass production, which is essential to maintain animals through the dry seasons. Rambau *et al*. (2016) reported that high lignin values result in decreased DM and CP degradability thus leading to nutrient deficiency. Morrison *et al*. (1990) reported that reducing the levels of lignified cells in plants can improve forage degradability, and this is because lignin blocks the digestion of fibre polysaccharides by microbial enzymes. Lower forage intake together with grazing animal production are subject to the dynamics connected with the cell wall composition, in that composition, polysaccharide fibrous degradation in the rumen is affected by lignin which is the key limiting factor (Lindgren & Lindberg, 1998; Manyedi *et al*., 2017).

The results show that *E. chloromelas* had the highest DMD36 and DMD48 values on Clovelly and Avalon soil types. According to Marais (2006), the grazing animals' health, reproduction and growth are subjective to available forage feed, therefore lower digestibility of forage leads to reduced nutrient availability, leading to reduced energy level. Other authors such as Torell *et al*. (2000) and Javed *et al*. (2008) also suggested the possibility that the amount of leaf and stem materials could also influence digestibility, however, the current study did not target the digestibility of leaves and stems. According to O'Connor and Danckwerts (1995), climate, soil nutrients, and fire are some of the extrinsic influencers on the productivity, composition and structure of vegetation types within any particular region. Tainton (1999), stated that the production and survival of grasses may be influenced by general climatic conditions such as temperature, humidity, rain and moisture within a given area. Minson and Mcleod (2006) reported that animal production through pasture grazing is commonly reduced due to the grass DMD being low, and suggested that this was a consequence of limited grass growing period, thus suggesting pastures should be given rest time to regrow native grass species.

Digitaria eriantha, Aristida congesta, Eragrostis chloromelas, Eragrostis curvula, Eragrostis plana and *Eragrostis gummiflua* had high levels of lignin, which were previously reported to have undesirable effects on degradability thus decreasing nutrient availability. Indeed, this study shows that lignin is negatively associated with the degradability of fibre, thus suggesting that the differences in DMD might be due to variations in lignin content of the plants (Huws *et al*., 2014). The effect of soil type on *in vitro* ruminal DMD of grass species showed little variation across different incubation intervals 12, 24, 36, 48 and 72 hours. Whilst other authors such as Jung and Allen (1995) together with Wilson and Mertens (1995) reported that these differences might be due to the plant's lignified parenchyma, different weight fractions, cuticle amount, and the stem's vascular bundles could also be the factors lowering plant degradation.

4.5 Conclusion

Most grass species harvested from this study were found to have low levels of minerals indicating that mineral imbalances may occur in animals using these rangelands. The mineral status of these animals needs to be monitored and corrected where required. Most grass species were deficient in Ca, Fe, P and Mg indicating the need to supplement with mineral licks. Findings from this study also showed that most of the grass species across all selected rangeland sites had high fibre and low protein thus will require protein supplements to improve animal productivity, this will also improve the ruminal microbial and dry matter degradability.

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5 CHAPTER FIVE: GENERAL DISCUSSION

5.1 Discussion

The results from this study showed that out of 31 grass species found and identified in selected rangeland sites; *D. eriantha, A. congesta, E. chloromelas, E. curvula, E. plana,* and *E. gummiflua* grass species were found to be dominantly and commonly distributed across all the soil types, this also indicates that there is a similarity in vegetation across the studied soil types and correlates with the soil factors in terms of nutrition, pH, and organic matter. As such, *A. congesta, E. chloromelas, E. plana,* and *E. gummiflua* grass species may be used as dominant indicator species for rangeland conditions. *Eragrostis chloromelas* dominance in clay soil type indicated a moderate rating condition. The dominance of *E. chloromelas*, *D. eriantha,* and *E. gummiflua* indicated selective grazing to moderate condition for the rangelands. The dominance of *E. plana* on Avalon and Clovelly soil type indicated moderate condition. The dominance of *D. eriantha* on Hutton soil type indicated selective grazing to moderate rating condition. The *A. congesta* grass species was found to be rare on Clovelly soil type which indicated an optimal rangeland condition.

Most of the grass species harvested across the studied soil types were found to be deficient in P and Mg levels, which were below the normal requirement for P (1.2-4.8 g/kg DM) and Mg (1-2.5 g/kg DM) range level for ruminants. To balance nutrition, mineral licks should be provided. From this study, there was variation in macro- and micro-minerals between the grass species across the selected rangeland sites. The concentration of minerals was either high or below the recommended requirements for livestock and between these findings reflected changes in soil nutrient status (Zafar *et al*., 2007). However, Ca levels were mostly within the normal ruminant requirements, these results safeguard that the grazing animals would rarely encounter bone problems or diseases or any other metabolic chronic condition associated with Ca deficiency. Therefore, it could be likely that livestock grazing from these areas may experience complications linked with imbalanced mineral concentration, and these problems require balancing with supplementary feed (Javed *et al*., 2008).

This study showed that the Hutton soil type has the highest number of high palatable plants growing in the area compared to the Avalon soil type which contained the lowest number, however Avalon soil type had the highest number of moderately palatable plants, whereas Clovelly was found to have the highest number of non-palatable plants. This study also shows that there was no variation to available biomass production concerning the grazing capacity within all the selected communal grazing lands since lower biomass yield was found on Avalon soil type and this could be due to the low grazing capacity compared to Clovelly and Hutton soil types which can be attributed to heavy grazing intensity. The results from this study showed that Avalon soil type had the highest grazing capacity compared to Hutton and Clovelly soil types which showed a similar grazing capacity. From this study, there was a variation in plant height and tuft diameter of the grasses throughout the three communal rangelands. This could be due to unlimited and simultaneous access of animals into the grazing areas. The resultant high grazing intensity and stocking rates could have influenced plant height and tuft diameter. Increaser iii and Increaser I species were the most affected because unsupervised animals would target these desired or high/most palatable grass species. Studying these vegetation factors would assist rangeland managers to track and manage overgrazing, overstocking, and overpopulation in these grazing areas (Moyo *et al*., 2010).

The outcomes from the study displayed a little variation between the dominant and common grass species in degradability, and most of the grass species from this study showed little variation in their DMD values. Results for the grass species fermentation based on *in vitro* degradability showed that most of the harvested grass species from the studied soil types had low ADL values and had high DMD72 hour values which mean animals grazing from this areas would have increased energy and productivity thus recommending this grass species as potential feed. However, due to nutrient deficiency in some of the grass species, supplementation would be necessary to secure balance in terms of nutrition. Studies by Gizachew and Smit (2012) recommended the use of non-conventional and conventional protein supplements making low CP values and high DM to be improved.

The results again displayed little variation on fibre contents observed between grass species, and other studies have mentioned that climate conditions, species lineage, soil type or fertility may influence the grass's chemical composition (Francisco *et al*., 2014). This grass species may sustain the ruminant animals the grazing animals' requirements compared to grasses with low CP values. Also results from the Hutton soil type showed that *E. curvula* along with grass species *E. plana* found growing on Clovelly soil type and *E. gummiflua* from Avalon soil type had low CP values which were below the normal standard required for animal nutrition. Low values of crude protein are reported to negatively affect the rumen microbes' cellulolytic activity leading to weight loss problems in ruminants. It is, therefore, important to negatively affect the rumen microbes' cellulolytic activity provide protein supplements to animals grazing pasture plants with low CP values. This study reports higher levels of NDF from above 600 g/kg and ADF from above 300 g/kg, whereas DM and OM values were from above 800 g/kg. Lindgren and Lindberg (1998) reported that native pasture's fibre and CP levels differ based on the grass species, and the same may be concluded in this study as well. The findings from this study also validated the archived reports which associate grass maturity, high lignin and high fibre to be inversely proportional to the grass quality (Mlay *et al*., 2006). To answer the questions that were initially asked from this study: This study results displayed little variation in grass species composition, distribution, biomass production potential, and nutritive values between the selected communal areas. Also, the soil type scarcely affected the values for the grass species in terms of biomass and nutritive values.

5.2 Recommendations for future research

Since several studies have reported that seasonal changes (winter, summer, spring, autumn) have an effect on plant nutritional accessibility and plant growth this leads to fluctuations in nutritional parameters depending on the harvested season. Further longitudinal studies may be carried out to study and compare the yield, distribution and nutritive value of grass species across seasons. This information will assist rangeland managers to improve and arrange better grazing systems to maintain balanced nutrition throughout the seasons.

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6 APPENDICES

Appendix 1. Template for grass data collection

Study area…………………………….

Date …………………………………..

GPS Co-ordinates ……………………..

Species (Measurements 1m^2) Density Height Diameter DM