ASSESSMENT OF VEGETATION DIVERSITY AND RANGELAND CONDITION IN THE HIGHVELD COMMUNAL GRAZING LANDS OF SWAZILAND

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ABSTRACT

Determination of correct stocking rate based on current rangeland condition still remains a big challenge to livestock farmers. Assessment of vegetation diversity and current rangeland condition was carried out in four communal rangelands, namely Siphocosini, Hawane, Motshane and Nkhaba. The rangeland condition assessment method employed in this study was the ecological condition index (ECI) method. Grass species composition and dry matter were estimated using the point-intercept method and the direct harvest method using a metal frame (quadrat) respectively. Vegetation diversity was high. A total of 16 grass species were identified. Of these, 9 species were strong perennials and the remaining 7 were annuals. In addition, 5 species were identified as highly palatable, 6-moderately palatable and 4-less palatable species. The proportion of highly, moderately and less palatable grass species were significantly different ($P<0.05$) among the grazing areas. Four grass species were common in the four rangelands and they are *Digitaria ternata, Paspalum scrobiculatum, Eragrostis plana and grass like species.* Soil pH ranged between 4.3-4.98. Soil N ranged between 0.11% and 0.13%. The Ca content varied between 1.4 cmolc Kg^{-1} and 4.28 cmolc Kg^{-1}. Dry matter yield at Motshane, Siphocosini and Nkhaba was significantly higher than that at Hawane. Frequency of bare patchiness differed significantly ($P<0.05$) among the rangelands. The rangeland condition was found to be fair and the actual stocking rate was 0.4 HA/LSU in contrast to the recommended stocking rate of 3-4 HA/LSU. This is indicative of serious overstocking that usually leads to rangeland degradation. Reduction of livestock numbers and rangeland rehabilitation programme should be initiated to address the current problem in these communal grazing areas.

Keywords: Rangeland condition, Diversity, Stocking rate, Rehabilitation, Communal grazing.

TABLE OF CONTENTS

ABSTRACT .... **ii**

TABLE OF CONTENTS .... **iii**

ACKNOWLEDGEMENTS .... **vii**

DEDICATION .... **viii**

DECLARATIONS .... **ix**

LIST OF TABLES .... **x**

LIST OF FIGURES .... **xi**

APPENDICES .... **xii**

CHAPTER 1 .... **1**

1.0 INTRODUCTION **1**

1.1 Background information about Swaziland 1

1.1.1 Country location and physiography 1

1.1.2 Orientation of the study 4

1.2 Statement of the problem 7

1.3 Objectives of study 7

1.4 Hypotheses of study 7

1.5 Significance of study 8

CHAPTER 2 .... **10**

2.0 LITERATURE REVIEW **10**

2.1 The Grassland biome 10

2.2 The importance of grasslands 11

2.3 Grasses and grazing 13

13

2.4 Effects of grazing...

2.5 Uses of rangelands and management systems in Swaziland.. 15

2.6 Rangeland assessment methods... 18

2.6.1 Method based on ecological principles... 19

2.6.2 Weighted palatability composition.. 20

2.6.3 Benchmark method.. 21

2.6.4 Ecological index method.. 21

2.6.5 Key species method... 22

2.6.6 Weighted key species method... 22

2.6.7 Subjective method.. 23

2.7 Ground cover.. 23

2.7.1 Techniques used to determine cover... 25

2.7.2 Point intercept.. 26

2.7.3 Forage production and biomass.. 27

2.7.4 Techniques used to determine biomass.. 27

2.8 Range trend and stocking rate.. 28

2.9 Rangeland condition... 31

2.10 Rangeland degradation.. 31

2.9.1 Causes of rangeland degradation in communal rangelands..................................... 32

2.11 Importance of vegetation diversity... 33

2.12 Grazing management... 35

2.12.1 Stocking rate and intensity.. 36

2.12.2 Grazing system and rest periods.. 37

2.12.3 Fires.. 39

2.12.4 Feed supplementation.. 40

2.12.5 Types of ranges identified in Swaziland.. 40

2.13 Rangeland condition and diversity as an indicator of rangeland condition........... 42

CHAPTER 3 .... **43**

3.0 MATERIALS AND METHODS **43**

3.1 Description of study area 44

3.2 Site selection and layout 44

3.3 Data collection 45

3.3.1 Grass species composition and dry matter production 45

3.3.2 Estimation of rangeland condition 45

3.3.3 Species identification and classification 46

3.3.4 Vegetation sampling and chemical analysis 46

3.3.5 Soil sampling and analysis 47

3.4 Data analysis 47

CHAPTER 4 .... **49**

4.0 RESULTS **49**

4.1 Grass layer 49

4.2 Soil nutrients 54

4.3 Composition of common grass species 55

4.4 Life forms of herbaceous layer 59

4.5 Dry matter yield and bare patchiness 59

4.6 Plant nutrients 60

4.7 Stocking rate and rangeland condition 62

CHAPTER 5 .... **63**

5.0 DISCUSSIONS **63**

5.1 Soil analysis 63

5.2 Grass layer........ 64

5.3 Common grass species........ 65

5.4 Dry matter yield and bare patchiness........ 67

5.5 Stocking rate and rangeland condition........ 67

5.6 Plant nutrients........ 69

5.7 Practical application and implications........ 69

CHAPTER 6........ 70

6.1 Conclusion........ 70

6.2 Recommendations........ 71

REFERENCES........ 72

APPENDICES........ 86

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DEDICATION

This thesis is dedicated to God for his leadership and guidance in carrying out this piece of work, my mother, Thandi Dlamini, who was there for me when I was sick, entire family and friends. Mum, without your prayers and love, I wouldn't be standing today.

DECLARATIONS

I, Leslie Velibanti Mapako, declare hereby that this study is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

I, Leslie Velibanti Mapako, grant The University of Namibia the right to reproduce this thesis in whole or in part, in any manner or form, which The University of Namibia may deem fit, for any person or institution requiring it for study and research; providing that The University of Namibia shall waive this right if the whole thesis has been or is being published in a manner satisfactory to the University.

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LIST OF TABLES

Page

1. Classes of range condition...19
2. Life forms, desirability, ecological grouping and occurrence of grass species in Motshane rangeland...50
3. Life forms, desirability, ecological grouping and occurrence of grass species in Hawane rangeland..51
4. Life forms, desirability, ecological grouping and occurrence of grass species in Nkhaba rangeland...52
5. Life forms, desirability, ecological grouping and occurrence of grass species in Siphocosini rangeland..53
6. Rangeland condition based on the ecological condition index method for each site..54
7. Soil pH, nitrogen (N) and macro elements (Mean ± SE cmolc Kg^{-1}) of top soil sampled from the rangelands..55
8. Soil micro elements (Mean ± SE) and phosphorous content of top soil sampled from the rangelands..55
9. Frequency of common grasses in the four rangelands..56
10. Frequency of life forms, bare patchiness and dry matter yield (DM) of the herbaceous layer in the rangelands..60
11. Chemical composition (%) of grass samples harvested from the four rangelands………61
12. Crude protein and fibre contents (%) of grass samples harvested from the four rangelands...61

LIST OF FIGURES

Page

1. Map of Swaziland showing the ecological zones..3
2. Graph showing the frequency of common grass species in Motshane........................57
3. Graph showing the frequency of common grass species in Hawane...........................57
4. Graph showing the frequency of common grass species in Siphocosini.....................58
5. Graph showing the frequency of common grass species in Nkhaba..........................58

APPENDICES

Page

A. Summary of ANOVA...86

B. Estimation of rangeland condition...87

C. Common and Scientific names of grasses indentified in the study area............................87

D. Pictures from sampling sites...88

CHAPTER 1

INTRODUCTION

1.1 Background information about Swaziland

Except where indicated, the information in this section has been extracted from the Swaziland Environment Action Plan handbook (2003) prepared by the Swaziland Ministry of Natural Resources and Environment.

1.1.1 Country location and physiography

Swaziland lies between latitudes 25^0 and 28^0 south and 31^0 and 32^0 east in the South Eastern part of Africa. The country is landlocked and covers an area of 17 364 km^2. It is bounded by South Africa in the north, west and south and by Mozambique on the east. It lies within the Maputoland centre of plant diversity an area reported to have the greatest biodiversity in Southern Africa. The population of Swaziland is estimated to be 1.1 million.

Swaziland is located between the Transvaal plateau (reaching over 1500 metres) and the coastal plains of Natal, Mozambique and NE Transvaal. Thus the western part of the country lies in an escarpment area, and the eastern part in the zone of the coastal plains. Separating the Swaziland coastal plains from the Mozambique coastal plains is the Lebombo ridge. Following is a general description of the main physiographic regions (Remmelzwaal, 1993) with an indication of the percentage each makes of the total land area of the country.

With its divergent geology, climate and subsequent landforms, the physiographic regions within the country's boundaries are very distinct. Swaziland's physiography has recently been reclassified primarily on the basis of landforms, elevations and secondly on geology and land forms. A distinction is now made between six physiographic regions; Highveld, Upper Middleveld, Lower Middleveld, Western Lowveld, Eastern Lowveld and the Lubombo Range.

The Swaziland **Highveld** (33%) is the upper part of an overall escarpment, consisting of a complex of steep slopes between low and high levels, dissected plateaux, plateau remnants, and associated hills, valleys and basins.

The **Upper Middleveld** (14%) consists of a strongly eroded plateau remnants and hills at an intermediate level of the overall escarpment. It also contains structurally defined basins in relatively protected positions, which are only weakly eroded.

The **Lower Middleveld** (14%) is basically the piedmont zone of the escarpment, characterised by generally strongly eroded foot slopes. The overall slopes are predominantly moderate and the zone classifies at the first level as a plain.

The Lowveld plain consists of sedimentary and volcanic Karoo beds versus the igneous and metamorphic rocks of the Highveld and Middleveld. The Lowveld is subdivided into the higher **Western Lowveld** (20%) on sandstone or claystone, and the lower **Eastern Lowveld** (11%) on basalt.

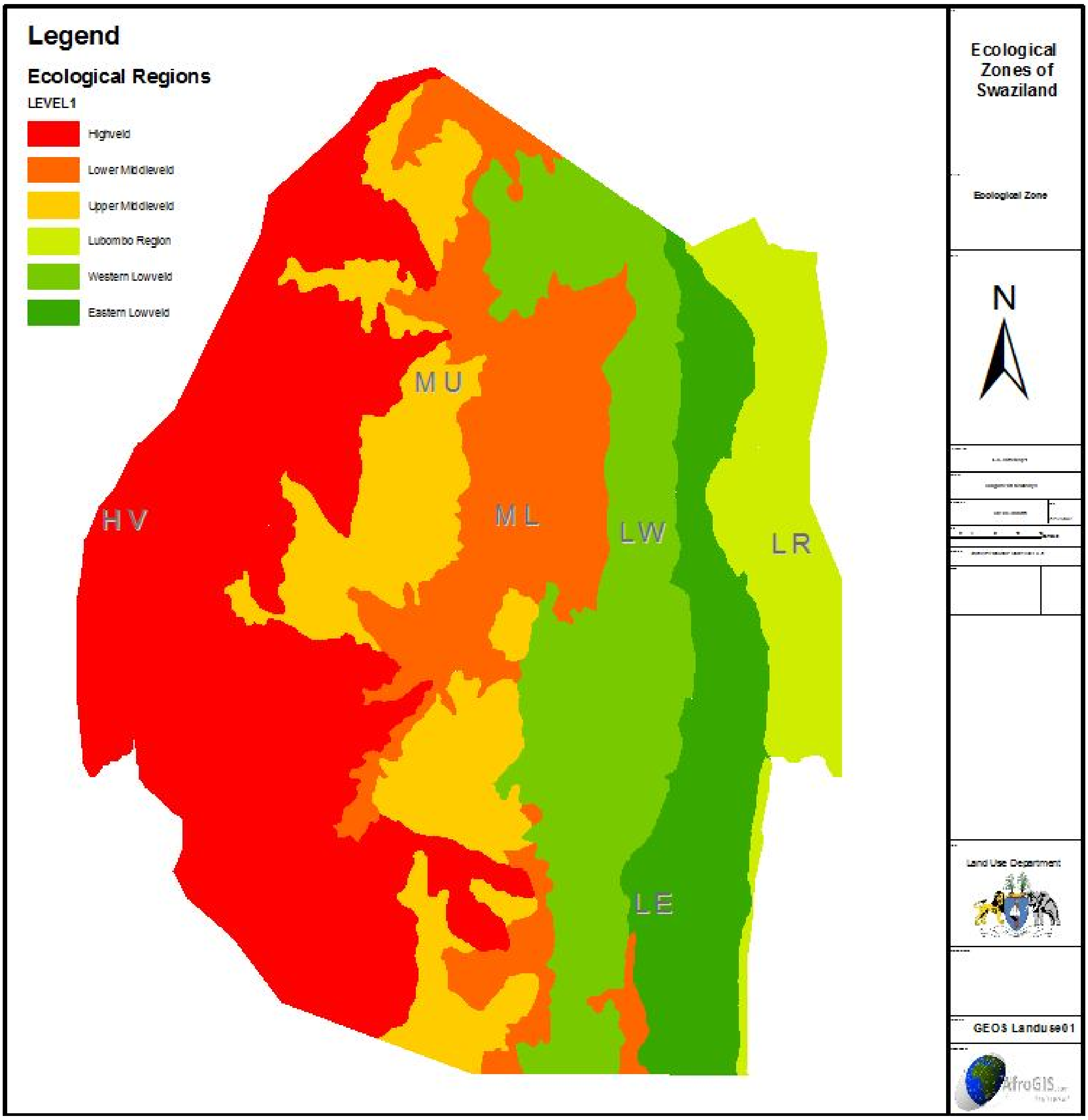

Figure 1. Map of Swaziland showing the ecological zones.

1.2 Orientation of the study

According to Sweet and Khumalo (1994), Swaziland occupies a total area of 17 370 km^2 of which approximately 63% can be considered suitable for livestock production. There are two main types of rangeland tenure and usage in Swaziland: Swazi Nation Land (SNL), which is mainly communal and held in trust by the King for the Swazi nation and Title Deed Land (TDL), which is mainly private ranching. Commercial agriculture is found under the TDL tenure system. These include large-scale irrigation farms, private ranches and government ranches. Subsistence farming is characterised by production of staple foods and the extensive livestock farming on the SNL tenure system. Furthermore, four major agro-ecological zones have been recognised and these are Highveld, Middleveld, Lowveld and Lubombo. The mountainous Highveld due to steep slopes experiences incidences of frost; has sour grasses and poor soils; is used mostly for grazing. Sour grasses refer to grasses that are only palatable when growing and become unpalatable when mature. Only 3% of the region has arable land of good quality soil (Anon, 2008).

In Swaziland rangelands (natural grasslands) are the major grazing resources for the country's livestock, providing food, water and space. Most of the livestock reared in Swaziland are found on SNL. Livestock particularly, cattle, are held as a store of wealth, especially on SNL. Sweet and Khumalo (1994) reported that cattle provide the owner with outputs, such as milk, meat, manure and draught power. Most Swazi families have their livelihood solely dependent on livestock rearing. Solomon *et al.* (2007) also allude that rangelands represent a valuable economic resource as well as means of subsistence to the people of Southern Africa.

Grazing pressure has undoubtedly intensified in the communal grazing areas of Swaziland due to increase in livestock numbers (Kunene, 2005). Such increase in livestock numbers in the Highveld is widely known to cause changes in soil characteristics, vegetation structure, composition and productivity, and consequently in the condition of rangelands (Solomon, 2003; Smet and Ward, 2005). In southern Africa, livestock grazing is often regarded as one of the main causes of rangeland deterioration (Warren and Khogali, 1992). Studies by Hiernaux and Turner (1996) in West African Sahel showed that increased grazing pressure can lower forage production by 50% or more, while Hiernaux *et al*. (1988) in the same region reported that increased grazing pressure might limit the following year's production of annual rangelands through depletion of seed bank. Another reason emphasised that ecological deterioration in savannah rangelands may not result from historical use only, but it could also be associated with external interventions such as dip tank and water development activities that eventually could lead to deterioration of the pattern of communal grazing systems and reduced grazing capacity (Ayanna and Baars, 2000; Solomon *et al*., 2007b).

For the last few decades, there has been a growing concern that the rangelands in Swaziland, particularly the communal ones, have been extensively deteriorating. At least, part of the failed efforts to avert the situation can be attributed to lack of any generally applicable methods of appraising the conditions of the rangelands. The concept ‘rangeland condition’ has been used to describe the ‘state of health’ of rangelands in terms of its ecological status, resistance to soil erosion and its potential to produce forage for sustained optimum animal production (Trollope *et al*., 1990). The purpose of condition assessment is to quantify the spatial and temporal changes in vegetation and soil based on a concern for both short and long-term productivity, as well as ecological integrity of rangelands. In Swaziland, the severity and magnitude of ecological deterioration in the Highveld rangelands is little understood. In particular, there has been no in-depth studies directly investigating herbaceous productivity, bush encroachment, soil seed bank and soil characteristics in such areas.

Subjective and quantitative techniques have been used in rangeland condition assessment and the choice of the method or factors to be used should depend on the local conditions. In general, in any assessment of a rangeland ecosystem composed of different vegetation components, rangeland monitoring must incorporate three tiers of assessments, i.e., the herbaceous layer, the soil and the tree-shrub layer. In the semi-arid savannas of Swaziland, grass and woody vegetation are more sensitive-indicators of ecosystem change (Solomon *et al*., 2007a), easier to perceive and to measure than soil. Several studies also identified soil characteristics as determinant factors of changes in the productivity, structure and composition of vegetation (Seastedt *et al*., 1991; Snyman, 2002). Therefore, a study of these aspects of soil properties in the Highveld is of paramount importance to predict the rate of ecosystem change (Schimet *et al*., 1991; Abule *et al*., 2005), and to explain the impact of disturbance on soil (Solomon, 2003).

1.3 Statement of the problem

Observations and reports (Solomon *et al.*, 2007) have shown that communal rangelands in the Swaziland in general and in the Highveld in particular are deteriorating. This is mainly characterised by loss of herbaceous vegetation cover, soil erosion and bush encroachment. The rangelands of the Highveld are used to support large populations of domesticated animals and humans. With increase in human and animal populations there is a tendency to graze too many animals on the land and because Swazi rangelands are open to communal use, there is little regulation of animals that utilise the range. It has been observed that rangelands of the Highveld carry a total of 50 000 cattle (MOA, 2010), and the area for grazing is 98 000 Ha which brings the stocking rate to 1.96 Ha/LSU, against a recommended stocking rate of 3-4 Ha/LSU. This overstocking has resulted in overgrazing which in turn has caused (i) the loss of vegetation, (ii) loss of plant cover; (iii) soil erosion, (iv) loss of soil fertility and a (v) reduced capacity by the land to support vegetation. Bare patches of land are common sight as you move about the rangelands, clearly showing that the rangeland areas are overgrazed. There is at the moment lack of adequate information on the state of health of these rangelands, the biodiversity condition, and the extent of degradation and as a result no area specific intervention.

1.4 Objectives of the study

1.4.1 General objective

The general objective of this study was to assess the condition of the grasslands in the Highveld communal grazing areas of Swaziland and to therefore develop a set of intervention strategies to mitigate and restore vegetation diversity and grazing condition thereof.

1.4.1.1. Specific objectives

The specific objectives were to:

1. Determine vegetation diversity and species composition/distribution of the herbaceous layer.
2. Determine current stocking rate and vertical spatial utilisation (animal species composition) of the vegetation
3. Determine the chemical/physical status of the soil.
4. Determine the current condition of the rangeland.
5. Evaluate the nutritive value of common grasses.

1.5 Research hypothesis

1. There are no differences in rangeland condition, dry matter yield, bare patchiness, and soil and plant nutrients among the four rangelands.

2. There are significant differences in rangeland condition dry matter yield, bare patchiness, and soil and plant nutrients among the four rangelands.

1.6 Significance of the study

This study sought to determine the state of vegetation diversity in the communal rangelands of Highveld and further determine the current condition of the rangelands. The study sought to come up with recommendations to ensure proper and sustainable management of the rangeland. This would consequently be of much benefit to the lives of the farmers as animal production and trade would increase with improved livestock and environmental conditions. Improved management system is also likely to protect biodiversity.

The study was expected to yield the following benefits: Indicate (and hence sensitise to the authorities) the state of the rangeland which in-turn would inform the extent of grassland degradation; provide valuable information that may provide baseline information to formulate rangeland management and improvement plan by the country's Ministries of Agriculture and Environment; farmers stand a chance to benefit from the information gathered during the study as it would be made available to the extension staff who will mount programs to mitigate and restore rangeland condition.

Furthermore, a thorough knowledge of Highveld's vegetation is essential to the formulation of comprehensive land use policy for the area. This study therefore, filled in the gaps currently existing as far as vegetation diversity and the condition of the rangeland of the Highveld are concerned.

CHAPTER 2

LITERATURE REVIEW

2.1 The grassland biome

The Highveld of Swaziland lies in the grassland biome. According to (Bredenkamp *et al.* 1996), the Grassland Biome is found primarily on the high central plateau of South Africa, and the inland areas of KwaZuluNatal and the Eastern Cape. The topography is mainly flat and rolling, but includes the escarpment itself. Altitude varies from near sea level to 2 850 m above sea level. The Highveld of Swaziland lies at an altitude between 1000-1500m (Sweet and Khumalo, 1994). Grasslands (also known locally as Grassveld) are dominated by a single layer of grasses. The amount of cover depends on rainfall and the degree of grazing. Trees are absent, except in a few localised habitats. Geophytes are often abundant. Frosts, fire and grazing maintain the grass dominance and prevent the establishment of trees.

There are two categories of grass plants: sweet grasses have lower fiber content, maintain their nutrients in the leaves in winter and are therefore palatable to stock. Sour grasses have higher fiber content and tend to withdraw their nutrients from the leaves during winter so that they are unpalatable to stock. At higher rainfall and on more acidic soils, sour grasses prevail, with 625 mm per year taken as the level at which unpalatable grasses predominate. C_4 grasses dominate throughout the biome, except at the highest altitudes where C_3 grasses become prominent (Bredenkamp *et al.*, 1996).

Grass plants tolerate grazing, fire, and even mowing, well and most produce new stems readily, using a wide variety of strategies. Overgrazing tends to increase the proportion of pioneer, creeping and annual grasses, and it is in the transition zones between sweet and sour grass dominance that careful management is required to maintain the abundance of sweet grasses. The Grassland Biome is the mainstay of dairy, beef and wool production in South Africa. Pastures may be augmented in wetter areas by the addition of legumes and sweet grasses. The Grassland Biome is the cornerstone of the maize crop, and many grassland types have been converted to this crop. Sorghum, wheat and sunflowers are also farmed on a smaller scale (Bredenkamp *et al.*, 1996).

Urbanisation is a major additional influence on the loss of natural areas - the Witwatersrand is centred in this biome. The Grassland Biome is considered to have an extremely high biodiversity, second only to the Fynbos Biome. Rare plants are often found in the grasslands, especially in the escarpment area. These rare species are often endangered, comprising mainly endemic geophytes or dicotyledonous herbaceous plants. Very few grasses are rare or endangered. The scenic splendor of the escarpment region attracts many tourists (Bredenkamp *et al.*, 1996).

2.2 The importance of grasslands

Skerman *et al*. (1990) allude that although the great importance of grasslands lies in providing sustenance, grasses also serve humanity in other ways. Grass may be used for building homes and furniture (walls, thatch, matting and brooms), lawns, sport-fields and as components of some cosmetics and medicines. A natural grassland is a plant community in which the dominant species are perennial grasses, there are few or no shrubs and trees are absent. Usually associated with the dominant grasses are less abundant grass species and a variety of other herbaceous plants, both annual and perennial types which at certain times of the year give a characteristic aspect to the plant community.

Grassland is one of a number of seral phases of vegetation. The vegetation structure is dynamic, rather than static. One ecological association follows upon, and grows in consequence of, its predecessor in a well-marked and orderly sequence. One association therefore acts as a nursery to its immediate successor. This series of successional phases, from the first to the last, is referred to as the sere, grassland forming one characteristic phase of that sere (Skerman *et al*., 1990).

Grasslands are of vital importance for raising livestock for human consumption and for milk and other dairy products. Grassland vegetation remains dominant in a particular area usually due to grazing, cutting, or natural or manmade fires, all discouraging colonisation by and survival of tree and shrub seedlings. Some of the world's largest expanses of grassland are found in African savannah, and these are maintained by wild herbivores as well as by nomadic pastoralists and their cattle, sheep or goats (Skerman *et al*., 1990). Grasslands may occur naturally or as the result of human activity. Grasslands created and maintained by human activity are called anthropogenic grasslands. Hunting people around the world often set regular fires to maintain and extend grasslands, and prevent fire-intolerant trees and shrubs from taking hold (Skerman *et al*., 1990).

2.3 Grasses and grazing

The composition of rangelands is not only a function of short-term or long-term climatic variation, but, importantly, a result of past grazing regimes. Effects of grazing regimes have been studied and reported repeatedly (see, for example, Harrington *et al.*, 1984; Westoby *et al.*, 1989; Tainton, 1999 and Rothauge, 2006). Generally, different species of grass also differ in their response to grazing; while grazing may be detrimental to some species, others will disappear if they are underutilised (McNaughton, 1993; Ryerson and Parmenter, 2001; Rothauge, 2006). Similarly, not all grasses are equally acceptable to grazers; while some are preferentially selected (Rothauge, 2006), others seem to be avoided.

The degree to which individual species may cope with defoliation regimes, as indicated by changes in their abundance in the rangelands, has been used to classify grasses as being *increasers* or *decreasers* (Hardy *et al.*, 1999; Vesk and Westoby, 2001). The presence or absence of species, and the rate at which their abundances change within the rangeland may thus be used to assess the impact of management regime (Westoby *et al.*, 1989; Hardy *et al.*, 1999).

2.4 Effects of gazing

A reduction in leaf area, and the rate at which it is reduced as a result of grazing, has a number of implications in the short, medium and long term. Most notable is the immediate reduction of photosynthetic tissue with a concomitant lowering of the productivity of the plant immediately after grazing. Depending on the severity of the defoliation, this leads to an immediate reduction in transpiration and therefore a reduction in the rate at which soil moisture is used. However, grazing not only affects the above-ground biomass, but also results in a decline and even complete cessation of root growth, depending on the rate of defoliation. Where grasses are heavily defoliated, root activity may not resume for several days (Tainton, 1999; Wolfson, 1999). Other studies have shown that grazing results in a shift in root production to the higher-lying soil layers (Schuster, 1964 as cited by Graz, 2004).

In the medium term light and moderate grazing induce the plant to produce additional tillers, and may therefore increase the productivity of individual plants (See the review by Wolfson (1999). Longer term change in rangeland composition is not only reflected in the present composition of the herbaceous plant component but also in the development of the soil seed bank. For instance, O'Connor (1994) ; Milton and Dean (1994) found a reduction in seed production of perennial grass species as a result of grazing or overgrazing; Peart (1989) found annual grasses to have a higher overall seed production than perennials in general.

The seed bank is further affected, as cattle remove the inflorescences of some grasses under sustained heavy grazing (O'Connor and Pickett, 1992). The inflorescences of other grasses, i.e. those with sticky inflorescences are generally avoided by cattle when they ripen (Ernst *et al*., 1992). The development of the soil seed bank has long-term implications for rangeland composition through recruitment. O'Connor and Pickett

(1992) showed, for instance, that seeds of perennial grasses had a limited longevity (3 years in their study), as opposed to those of annuals.

2.5 Uses of rangelands and management systems in Swaziland

The rangelands of Swaziland support diverse and dynamic ecosystems that sustain wildlife, game and livestock farming. Three main types of land use systems can be found: communal livestock grazing, commercial ranching and game reserves. These land use systems differ in management structure, animal diversity, management of grazing resources and products. In Swaziland, as in large parts of southern Africa, communal land is the most common land tenure and usage. Majority of the rural people in Swaziland derive their livelihood from subsistence farming, maintaining a diversity of livestock species on the communal rangelands. Livestock provide meat, milk and draught power and also represent a store of wealth (Dlamini *et al*., 2000). Most of the beef cattle in Swaziland are provided from the communal land tenure system.

The communal rangelands are not bound to a particular grazing strategy, and there are no specific rules that govern the movement as well as the number of animals to be kept over the grazing period. For these reasons the official view is that this land use has resulted in increased land degradation, and a number of policies have been introduced in southern Africa to halt this process (Annika, 2000; Smet and Ward, 2005). As regards to tenure, these have advocated the privatisation of land use, such as the establishment of fenced commercial cattle ranches. Commercial ranching is a well developed industry including private and government owned ranches. The commercial ranches are mainly used for beef cattle production and as centres for cattle breeding. Game reserves focus on eco-tourism and conservation, trophy hunting and red meat production. Most commercial livestock ranches and game reserves are managed by rangeland managers with secondary education and even some degree of tertiary education (Dlamini *et al*., 2000).

According to Anon (2005), the main land use in Swaziland is extensive grazing, of which communal extensive grazing covers approximately 50% of the country and commercial ranching 19%. Grazing takes places on natural grasslands, savannas and woodlands, which areas are also used for community forestry and natural resource extraction. The majority of the population live in farm households located on communal areas and are predominantly engaged in subsistence dry land farming, rain-fed crop farming and animal rearing. According to Holecheck *et al.* (2004), range management is the sum of extension actions by which it is expected to protect the veld and make the herd more productive. There is a list of activities that have been undertaken to achieve such: fencing programme, bush clearing, improved pasture and making hay, bull camps and building of new dip tanks (MOAC, 1982).

MOAC (1982) further states that, currently, the fencing of grazing areas for better management of the veld is almost confined to maximum input in Rural Development Areas (RDA) of which Motshane, Hawane, Siphocosini and Nkhaba are not part of. Motshane, Hawane, Siphocosini and Nkhaba are part of the minimum input RDAs where there are no funds earmarked for fencing. According to Sweet and Khumalo (1994), the current use and management influence the vegetation structure and composition often mask natural vegetation boundaries. The two types of land usage are ranching which is mostly on Title Deed Land (TDL) but also includes government and Tibiyo ranches on Swazi nation Land (SNL); and communal grazing which are all essentially on SNL. SNL designated as grazing areas are available for year round grazing while the reciprocal part of each grazing categories is mainly small scale arable land which becomes available to livestock approximately from May to September (Sweet and Khumalo, 1994).

According to Holechek *et al*. (2004), Range management has two basic components:

1. Protection and enhancement of the soil or vegetation complex

2. Improving or maintaining the output of consumable range products such as meat, fibre, wood, water and wildlife.

Holecheck *et al.* (2004) further stated that range management is based on the five concepts:

1. Rangeland is a renewable resource
2. Energy from the sun is captured by green plants and can be harvested by grazing animals;
3. Rangelands supply humans with food and fibre at very low energy costs compared to those associated with cultivated lands;
4. Rangelands productivity is determined by soil, topography and climatic characteristics; and
5. A variety of products including food, fibre, water, recreation, wildlife, minerals and timber are harvested from rangelands.

2.6 Rangeland assessment methods

Rangeland evaluation is an essential management tool for qualifying and quantifying change in range condition with the intention to monitor management effectiveness and indication of the necessary management inputs. Rangeland condition refers to the health status of the range based on its ability to produce forage in a sustainable manner. A similar definition was given by Trallope *et al.* (1990) based on ecological status, resistance of erosion and the potential for producing forage for sustained optimum livestock production. Rangeland assessment measures range deterioration and improvement changes in vegetation productivity of rangelands on short term or long term basis (Solomon *et al*., 2007). A rangeland becomes deteriorated when it shows a retrogressive shift on state of health. A rangeland in poor condition is characterised by high unpalatable vegetation, invaders and increasing poisonous plants and woody species. Soil indicators are low soil moisture, severe soil loss and gull formation (FAO, 1994). However, variation in species composition, stability of the soil surface and extent of soil erosion often indicate differences in range condition (Dyksterhuis, 1949, 1958 in Holechek, 2004; Daubenmire, 1984).

Different subjective and quantitative techniques are used in rangeland condition assessment and selection of methods is dependent on local conditions and targeted vegetation type. Assessment of rangeland ecosystem is composed of three types of assessment such as the herbaceous layer, the soil and the tree-shrub layer. Interpretation of rangeland condition assessment requires multiple perspectives and assessor accuracy in measuring changes and assigning correct interpretation of results (Abule *et al*. 2004, 2006; Warren, 2002). However it provides information for alternative management and planning for achieving optimum productivity of desired plant species and sustainable animal production (Danckwerts, 1989).

2.6.1 Method based on ecological principles

Dyksterhuis (1949, 1958 as cited by Holechek *et al*., 2004) approach stated that range condition can be measured in degrees of departure from climax. This approach assumed that climax can be determined from each site where excellent condition class would represent climax and poor condition for the most shifts from climax (Holecheck *et al*., 2004). Range condition classes have been developed and used to express different status of the rangeland (Table 1).

Table 1. Classes of range condition.

Range condition	**Percent of climax**
Excellent	76-100
Good	50-75
Fair	26-50
Poor	0-25

Source: Holechek *et al*. (2004).

The range condition classes are defined as follows:

(a) **Excellent.** The vegetation cover is “normal”, as expected under conditions of rainfall and good soil type than in dry areas and stony soils of less dense vegetation. The plants are vigorous and productive with good mulch cover between perennials.

(b) **Good.** The better species, mostly perennials, dominate but less desirable species are present. There are many bare patches without mulch and gully erosion is visible.

(c) **Fair.** Undesirable species with most annuals dominate and desirable species are weak and produce little seeds. There are many bare patches without mulch and gully erosion is visible.

(d) **Poor.** There is sparse, unstable vegetation cover of mostly annuals and undesirable species.

There is little or no mulch and serious wind and water erosion occurrence.

2.6.2 Weighted palatability composition

This method was proposed by Barnes *et al*. (1984), whereby the livestock production potential of a site is based purely on immediate forage production potential. Species are allocated palatability ratings which signify their productivity classes (Hardy and Hurt, 1989). Three palatability classes were described for the purpose of classifying grassland species: classes 1, highly palatable, class 2- intermediate, and class 3-unpalatable. Weightings of 3, 2 and 1 for classes 1, 2 and 3 respectively, are used to derive a palatability composition relating for each sample site (Hardy and Hurt, 1989). The palatability composition rating (PC) for each site is calculated as the sum of products of the relative abundance of each species and its weighting and is expressed as a percentage of the maximum PC to produce a scale ranging from 33.3 (all species in class 3) to 100 (all species in class 1). The PC values are converted to weighted palatability composition (WPC) by means of the following formula (Barnes *et al*., 1984). WPC= (PC-33.3) *100/66.7

2.6.3 Benchmark method

This method involves identification of benchmark site which are productive and stable and which would support long term animal production while conserving the water and soil resources (Tainton, 1999). This method compares veld condition of site to one which is in excellent condition in the same ecological zone. The proportional species composition of the site is calculated and species classified into their categories (decreaser, and increaser 1, 2 and 3), and a forage factor is subjectively allocated to each species within a group. The scores are added up to calculate a sum for each group and the groups are added to obtain a final score. The score is then compared to that of the benchmark site (Jordan *et al*., 1997).

2.6.4 Ecological index method (EIM)

The technique was first described by Vorster (1982), whereby the vegetation in the sample site is compared to that of a benchmark site of a similar trend to topography and area as the survey site. The vegetation is classified into a decreaser group, increaser groups and invader species. The categories are classified as follows.

(a) Decreaser species – Decrease in abundance with over-utilisation

(b) Increaser IIa species- Increase in abundance with moderate over-utilisation

(c) Increaser IIb species- Increase in abundance with severe over-utilisation

(d) Increaser IIc species- Increase in abundance with extremely severe over-utilisation

(e) Invader species – species foreign to the veld type

Relative index values of 10, 7, 4, and 1 are assigned to the five groups, respectively. A condition score of a particular sample site is the sum of the production of the proportion contributed by the different ecological groups and relative index values assigned to each group (Hardy and Hurt, 1989). The derived range condition index is used to calculate grazing capacity or to monitor range condition (Jordan *et al*., 1997).

2.6.5 Key species method

The method suggested by Mentis (1983) as cited by Tainton (1999) recognises that not all species encountered in the grassveld show the typical decreaser / increaser response to utilisation intensity. A few key species (only those that respond sensitively to grazing gradient) are identified and could be used to index veld condition in both veld types. The identified key species were *Themeda trianda, Tristachya leucothrix* and *Heteropogon contortus* (Heard *et al*., 1986 as cited by T**a**inton, 1999). The condition score for a sample site is calculated as the sum of relative abundances of the key species. The result is then compared to that of the benchmark, which is calculated in a similar manner. In further development of the method, key reaction species were represented by either individual species or group of species that exhibit a similar reaction to a particular grazing management treatment (Hurt and Hardy, 1989).

2.6.6 Weighted key species method

The method proposed by Heard *et al*. (1986 as cited by Tainton, 1999) modified the key species method by allocating weightings of the key species. The veld condition index is calculated as the sum of products of the proportions of the key species and associated weighting, (only responsive species are selected as key species) and the final score provide an indication of the position of the sample site along the grazing gradient and its relation onto the benchmark (Tainton, 1999).

2.6.7 Subjective method

The subjective method is a simple assessment technique which can be applied by extension workers and researchers without complications. The technique is based on a complete survey of the vegetation and soil surface condition (Van Zyl, 1986). Conditions regularly botanical composition, vegetation cover, vigour, soil surface as well as insect and rodents' damage are being assessed. The score from each class ranged from 1-10 and weights are also allocated to each of the class or sections. The scores from each class is multiplied by the applicable weights after which all the scores are summed up to an average index score (Van Zyl, 1986). The index is either used for monitoring purpose or to read grazing capacity from a rainfall table (Jordan *et al*., 1997)

2.7 Ground cover

Cover is defined as the vertical projection of the crown or stem of a plant into the ground surface (Elzinga *et al*., 1998 and Bohnham, 1989 as cited by Khumalo, 2006). Vegetation cover is the percentage of ground surface covered by vegetation material, and two types of cover are recognised. Basal cover is the area where the plant intersects the ground while aerial cover refers to vegetation above the ground surface.

Canopy cover serves as criterion for relative dominance within a community and important influence on interception of precipitation and soil temperature. Cover may be used by plant ecologist to describe total vegetative cover or by range managers to define cover of forage for livestock, or by foresters to describe basal area of merchantable timber. Cover is a common measure of community composition and is mostly directly related to biomass. A key advantage of cover as a vegetation measure is that it does not require the identification of individual (as density does), yet it is an easily visualised and intuitive measure (Elzinga *et al.*, 1998 and Bonham, 1989 as cited by Khumalo, 2006).

Disadvantage of cover measure (especially canopy) is that they can change dramatically over the course of growing season, while both frequency and density measure are fairly stable after germination is complete. The change in cover over the course of growing season may make it hard to compare results from different portions of large areas where sampling takes several weeks or a few months. Another disadvantage is that cover measures are sensitive to both changes in number (mortality and recruitment) and in vigour (animal biomass production) (Elzinga *et al.*, 1998 and Bonham, 1989 as cited by Khumalo, 2006). Basal cover is a reliable measurement for bunchgrasses, tussocks and tress. Cover is often expressed as a percentage value and in a dense or multilayered community total vegetative cover may exceed 100%. Cover can be measured directly with a quadrat charting or a pantographic method or an ocular estimation technique, a line intercept method or point intercept method (Bonham, 1989 as cited by Khumalo, 2006).

2.7.1 Techniques used to determine cover

There are several techniques used to sample or determine vegetation cover such as point intercept and Daubenmire cover method, (Fourier and Roberts, 1997, method of Kruger, 1983 as cited by Tefera, 2003 and Khumalo, 2006). Line intercept and point intercept methods are the most popular methods used to estimate cover. These methods are much more efficient and more accurate than the quadrat method. The line intercept method is perhaps the most useful method for measuring open growth, woody vegetation, and particular plant species with dense canopies. It is more difficult to use on plants with narrow canopies such as grasses, forbs and shrubs.

On the other hand the point intercept method is more useful for pastures and grassland (Elzinga *et al*., 1998 and Bonham, 1989 as cited by Khumalo, 2006). Both basal and canopy can be measured with the line intercept method. In this technique a line of tape measure is stretched between two stakes and basal width or canopy width of all plants touching the line or tape is measured. If basal cover area is needed then the line-intercept method is used. In this technique, a line of tape measure is stretched between 2 stakes and basal width or canopy width of all plants touching the line or tape is measured. If basal cover area is needed then the line is placed at ground level. The length of line and total length intercepted by vegetation is used to estimate percentage cover.

The line intercept method is also used to estimate species composition that is the percentage of total intercept made by individual species (Elzinga *et al*., 1998 and Bonham, 1989 as cited by Khumalo, 2006). For general survey, lengths of 10, 20, 50, and

100m are used to measure cover by both intercept and line-point. Tape is often used for lines, and location of the lines is permanently marked by steel stakes to allow monitoring over a long period of time. Some studies have used lengths of tape up to several hundred metres and lengths used are dependent on the type of vegetation. Cover in herbaceous communities can be estimated with short line (less than 50m) while long lines (50m or greater) should be used in some shrub and tree communities (Elzinga *et al.*, 1998 and Bonham, 1989 as cited by Khumalo, 2006).

2.7.2 Point-intercept

The point-intercept is the oldest method used to measure vegetation cover. The contact of a point on a vegetation part has been used extensively to measure cover. Individual points are represented by tips of sharpened pencil to a point, and cross – hairs telescopes or reflecting mirrors. Areas bounded by plots have been used extensively to obtain estimates of cover by species, total vegetation, litter, rocks and bare ground. Cover is measured by point intercept based on the number of hits on the target species out of the total number of points measured. Measured cover by points is considered the least biased and most objective of the three basic cover methods (Bonham, 1989 as cited by Khumalo, 2006). In either method, a single pin is lowered towards the ground and the first strike of any part of the vegetation becomes a canopy cover hit, if it strikes basal area of the plant it is basal hit. Per cent canopy or basal cover is calculated as the total number of hits divided by total number of pin placement multiplied by 100. The point-intercept method is frequently conducted along several transect lines which are regarded as the sample unit (Bonham, 1989 as cited by Khumalo, 2006).

2.7.3 Forage production and biomass

Biomass (weight) indicates the quantity of resources, such as water, used by a species in a community. It is the measures of how much of the community's resources are tied up in different species. Herbage production is the annual output of vegetative biomass and it is most commonly measured as a harvest of above ground standing crops usually at peak before plants start to deteriorate. Production varies each year depending on the favourability of growing conditions and sometimes can be increased by switching from heavy to moderate or light grazing intensive (Holechek *et al*., 2004). It has been discovered by Klipple and Bement (1961) as cited by Khumalo (2006) that improvement in forage from light grazing implementation occurs after 7 years. Light grazing has been shown to be a useful tool in improving forage production during the early stage of deterioration when desirable forage is still present but in low vigour (Holechek *et al* ., 2004).

2.7.4 Techniques used to determine biomass

There are several sample techniques and methodologies that have been developed to obtain estimates of herbaceous biomass. There are direct and indirect methods and a combination of direct and indirect methods. Selection of any one method depends on its merits and the objectives of measurement (Bonham, 1989 as cited by Khumalo, 2006). Harvesting or clipping is probably the most common direct method to estimate herbaceous biomass production. Vegetation biomass is harvested from the three dimension volume of the quadrat (height x width length) of a shown dimension.

Plant biomass that is not rooted in the quadrat but occupies space in the volume is harvested while portions of plant rooted in the quadrat that do not occupy the quadrat volume are not harvested. Vegetation samples are clipped and weighed by species, aggregates of species or life form categories and are standardised to oven or air dry weight. The height of clipping above ground level depends on the objective of data collection, it is best to clip all vegetation to ground level. The amount of material available for forage by herbivore class can be partitioned by plant species. Grazing capacity is described as the productivity of the grazing portion of a unit of vegetation and number of animal units maintained per unit area of land. The purpose is to maximise animal production per unit input without consideration of changes on botanical composition and soil stability (Danckwerts, (1982).

2.8 Range trend and stocking rate

Trend has been defined as the direction of change in range condition (Society for Range Management 1989, as cited by Khumalo, 2006. Trend ratings were initially used to indicate conditions for livestock grazing as indicated by increasing productivity, cover, and succession towards climax conditions. On the other hand, range condition refers to the state of health of the range. It has historically been based on the amount of climax vegetation remaining on the site. Changes in range condition scores over time are usually the basis for monitoring management effectiveness. If ranges are in poor or fair condition, management that is aimed at improvement may be indicated. Various studies reviewed by Vallentine (1990) and Holechek *et al.* (2004), as cited by Khumalo (2006), show that grazing intensity and stocking rate have more influence on wildlife habitat, vegetation composition and productivity, biodiversity, air quality and economic welfare of ranchers and non-ranching community than any other aspect of grazing (timing, frequency, type of grazing system).

Grazing intensity is the cumulative effects grazing animals have on rangelands during a particular time period. Stocking rate is the amount of land allocated to each animal unit for the grazeable period of the year (Holechek *et al*., 1999; Scarnecchia and Kothmann, 1982, as cited by Khumalo (2006). Heavy grazing intensities use above 50% of the available primary forage species; moderate grazing use 40 to 49% of the available primary forage species; conservative grazing use between 30 and 39% of the available forage species and light grazing involves use of 20 to 30% of available primary forage species. Light grazing intensities have been suggested as a potential method of lowering risk (Galt *et al*., 2000; Holechek *et al*., 2004) as cited by Khumalo (2006). Several range professionals have advocated the use of a 25% utilisation coefficient in arid and semi-arid areas (Lacey *et al*., 1994; Johnson *et al*., 1996; Galt *et al*., 2000) as cited by Khumalo (2006).

Broad studies from the salt desert (York *et al*., 1992) and the Chihuahuan desert (McCormick and Galt 1993) as cited by Khumalo (2006) indicate that proper grazing management and precipitation have the potential to increase forage production on ranges dominated by brush. These studies show major increases in forage plants and improvement in range condition over 30-40 year periods if grazing intensities were moderate to low, and precipitation was average or above average following drought. A review of 25 stocking rate studies in semi-arid or sub-humid rangelands in North America by Holechek *et al*. (1999) indicated that light grazing gave only slightly lower returns than moderate grazing when all studies were averaged. Holechek and Pieper (1992) and Winder *et al*. (2000) as cited by Khumalo (2006) concluded that conservative grazing was financially more effective than moderate grazing in the Chihuahuan Desert of New Mexico.

Heavy stocking consistently caused a downward trend in ecological condition; light stocking caused an upward trend, and slight improvement occurred under moderate stocking in a review by Holechek *et al*. (2004). Invariably, the most productive and palatable forage species (decreasers) showed a decline in production and cover under heavy stocking, while they tended to increase production under light stocking (Holechek *et al*., 2004). The longer the time involved, the more divergence there was in vegetation composition between heavy and light stocking. Generally these studies provide support for Dyksterhuis (1949) as cited by Khumalo (2006), theories of plant responses to grazing management. However, different stocking rates generally had more impact on forage production than plant composition. Grazing studies from other parts of the world are consistent with those from North America regarding rangeland trend and grazing intensity (Holechek *et al*., 2004). An analysis of over 50 grazing experiments in Africa also showed that rangeland successional trends were closely related to grazing intensity. Generally, rangeland ecological condition was stable under moderate continuous grazing, increased under light grazing and decreased under heavy grazing, as with Swaziland lowveld studies.

2.9 Rangeland condition

Vegetation condition is usually used to quantify rangeland condition because it is a reliable mirror of its ecological environments. Grass species composition plays a vital role as indicator of rangeland condition because grasses may vary significantly in their acceptability by grazing herbivores due to differences in palatability, and also due to phenological differences (e.g. rhizomatous, stoloniferous or tall tufted grasses) (Snyman, 1998; Solomon, 2003). Several studies identified chemical and physical properties of soil as determinant factors of changes in the productivity, structure and composition of vegetation (Seastedt *et al*., 1991; Snyman, 2002). Study of these aspects of soil properties is of paramount importance to predict the rate of ecosystem process (Schimet *et al*., 1991; Abule *et al*., 2005).

2.10 Rangeland degradation

A decrease in rangeland condition is often termed as rangeland degradation (Solomon, 2003). The vegetation indicators usually considered as indicative of rangeland degradation can be described as low grass cover, preponderance of grasses of low palatability, change from species composition where perennials predominate to one dominated by annuals - particularly forbs, and increase in woody vegetation density known as bush encroachment. Other indicators of decreased rangeland condition are decreased soil water availability, and livestock condition or productivity, which may, however, lag behind the deterioration in vegetation. Soil loss and formation of soil crust or gullies with increased soil erosion may also be regarded as the measure of the seriousness of rangeland deterioration. This is because these are reversed over extremely long period of time, and results in a reduction in productivity and affects future land use options (Wilson *et al*., 1984; Snyman, 1999).

2.10.1 Causes of rangeland degradation in communal grazing lands

The driving factor behind vegetation dynamics and deterioration of rangelands (grasslands and savannas) still remains a subject of controversy. The most important driving factors of controversy can be summarised as anthropogenic, climate and soil. In southern Africa, the view of many scientists is that the shift in vegetation is associated with anthropogenic activities, especially high cattle densities (Skarpe, 1986; Ringrose *et al*., 1996). Thus, overgrazing is considered as the most important cause of rangeland degradation. When the rangeland carries beyond its potential, the resultant overgrazing will cause a decrease of the palatable perennial plants in favour of less palatable undesirable vegetation and disrupt the population process of key palatable species. Besides, overgrazed rangelands with low plant cover have reduced soil nitrogen and organic matter levels.

High cattle densities and the resultant overgrazing are often associated in this region with communal rangelands, where uncontrolled management of grazing lands prevails. Furthermore, most users of the communal rangelands are in fight for survival and, thus, condition of the rangeland is not a priority (Smet and Ward, 2005). Some researchers in southern Africa, however, have argued that overstocking is not the primary driving factor. Climate and soil characteristics are considered the primary determinants of species composition and structure of vegetation communities in semi-arid and arid areas (O'Connor, 1985; Scholes and Walker, 1993). More emphatically, a characteristically marked year-to-year variability of rainfall has been identified as a primary determinant of compositional change in southern Africa savannas (O'Connor, 1985). This hypothesis suggests that grazing is inconsequential and that the community and system dynamics are mainly a function of rainfall variability, yet the current rationale for grazing management in this region is based on the premise of grazing as the main agent of compositional change.

Other external factors such as development of dip tanks and water sources, land alienation through privatisation, industrialisation and expansion of cultivation, have been most commonly cited as causes of deterioration of rangeland in Africa (Coppock, 1994). In Swaziland, ticks are controlled through a compulsory dipping control program. Kunene (2005) reported that there were 588 dip tanks operational in the communal rangelands of Swaziland, and there were 390 government run and privately owned dip tanks. Weekly dipping is compulsory during summer months (November-May) and bi-weekly in winter. The dipping of animals weekly result in the formation of cattle tracks that destroys vegetation cover and soil structure thus leading to soil erosion.

2.11 Importance of vegetation diversity

Vegetation diversity forms the basis of diversity in all the four structural components of the natural capital, these being functional diversity, ecological, genetic and species diversity (Miller, 2007). It provides human beings with natural resources such as food, energy, medicines and energy, natural services such as air, water purification, soil fertility, waste disposal, and pest control and generally provides aesthetic beauty in the environment and good feeling.

According to Schulz and Gray (2004) as cited by Mapaure (2010) the composition, diversity and structure of vascular plants are important indicators of an ecosystem's health. Plants are the source of primary production and the main determinant of habitat. When changes in vegetation occur they can have cascading effects through an ecosystem. Changes in species, structural diversity and the abundance of non-native species are common environmental concerns and are part of the international criteria for assessing sustainability of practices of some ecosystems. The essentiality of biodiversity is evident also in the biological wealth that keeps us alive and supports economies. Miller (2007) says that it supplies us with resources that "…pour hundreds of billions into the world's economy each year." In Swaziland, vegetation diversity provides the livestock with a variety of nutritional value. Animals do not consume every plant they come across, they are selective consumers. The more diverse the range is, the more chances for livestock to select nutritious and palatable herbage.

Diverse vegetation also provides medicinal benefits for the Swazi people. One of the most significant professions is traditional medicine, which is becoming even more prominent in the country. The traditional healers use these plants mainly for healing various ailments. They obtain their livelihood from these plant species. The Swazi people graze their livestock; they use medicinal plants to cure various ailments. Fruits and food provided by the various wild fruit plants and vegetables and animals from the rangeland provide for people's livelihood.

In addition, according to the Lesotho's Country Assessment report (1986), all the millions of plant species in existence play a significant role in maintaining the environmental conditions on which they themselves (plants) and humans depend. The biological processes such as nutrient cycling and photosynthesis carried out by plants and animals directly affect the atmospheric composition, temperature regulation, precipitation, radiation levels and other factors shaping life. Otherwise human beings would have nothing to eat, drink, wear and they might find themselves having a climate they cannot survive in. Thus it can be safely stated that human beings need biodiversity more than it needs them.

2.12 Grazing management

According to Sweet and Khumalo (1994) grazing management refers to the art of manipulating spatial and temporal distribution of grazing livestock to maximise the animal production objectives while maintaining an appropriate plant composition, density and structure. According to Wilson *et al.* (1990) change in rangeland ecosystem is inevitable as a consequence of grazing. Such change may be a reduction in cover through utilisation or a major long-term change such as shifts in species composition or range productivity. The essence of grazing management is the manoeuvring of these changes through the control of intensity and timing of grazing.

2.12.1 Stocking rate and intensity

According to Wilson *et al.* (1990), stocking rate refers to the number of animals or livestock units per hectare. Stocking intensity is the current number of animals per hectare of paddock or land area. Sweet and Khumalo (1994) state that stocking rate is said to be the fundamental principle of grazing management, stocking within the carrying capacity of the available area, that when it is practised all other management means are of secondary importance. Humphreys and Partridge (1995) concur when they state that stocking rate is the single most influential factor in pasture management. As the number of animals goes up, there is less good quality feed for each and the output per animal declines. Both the choice of stocking rate and the resulting stock intensity have a profound effect on the immediate and long-term animal productivity of the range (Wilson *et al.*, 1990).

Immediate effects include declining animal growth and productivity as stocking rate increases. The resilience of the pasture to grazing is exceeded at certain grazing pressure and a break occurs in the normal relationship between animal production and stocking intensity (Wilson *et al.*, 1990). In addition Humphreys and Partridge (1995) state that stocking pastures too heavily will damage the sward, allow weeds to invade and encourage erosion and increase the need for supplementary feeding in stress times. Furthermore, reducing stocking rates helps maintain native grasses that cannot stand high rates of utilisation.

To be effective, there is need to collect data on stocking rates in relation to range conditions in communal areas. There are guidelines according to Sweet and Khumalo (1994), for stocking rates in different vegetation units with simple methods for adjusting them according to local area conditions. Areas available for each community and each member's proportional rights must be defined. According to Khumalo, L. (Ocober 20 2008, personal communication), rangelands of Swaziland are overstocked. The recommended stocking rate for the vegetation unit in which the Highveld lie is 3-4 HA/LSU, however the actual is 1.7-2.1 HA/LSU.

2.12.2 Grazing systems and rest periods.

Grazing systems means different kinds of methods of allowing livestock to graze including rotational and continuous grazing with period of rest which are of great importance for seed set and for replenishment of root reserves (Sweet and Khumalo, 1994). Wilson *et al.* (1990) identify the following grazing systems:

2.12.3 Continuous grazing

This is where stock is distributed evenly over the available paddock. Animals are grazed for the entire grazeable period of the forage. One of the major practical problems of continuous grazing systems is their lack of flexibility. The structure of the grazing must be born in mind to prevent selection which may occur, to the detriment of the favoured species. Tainton (1981) states that selection still does occur due to dung and urine spots and first-bite sites, particularly at low stocking rates.

2.12.4 Rotational grazing

According to Tainton (1981), this type of management system requires grazing allotted to a group or groups of animals to be divided into at least one enclosure more than the number of animal groups. It is successive grazing in a rotation so that not all the veld is grazed simultaneously. The grazing area is divided into a number of paddocks, usually at least six, and the animals moved systematically from one paddock to the other in a rotation. The length of the grazing period depends on the stocking rate and herbage growth rate, may be 6-7days, after which the livestock is moved and the paddock rested (McIlroy, 1964). It enables control of livestock intensities in one area and reduces the extent at which the pasture is grazed selectively by confining a large number of herds, relatively to a small proportion of the veld. This offers them little opportunity for selection and moreover, may overcome disadvantages of over- and under-grazing.

Rest periods are the operating principle of rotational systems but can be incorporated into grazing management without formal grazing systems. This is what happens in communal grazing land in SNL where paddocking and fencing are impractical but selected areas can be given periodic rest by communal consent (Sombroek *et al.*, 1993). Rest periods are beneficial when applied during active growth phase of the forage plants which would be during summer months. Once dormant grass can be heavily grazed, cut or burned with little detriment but they are most susceptible to excessive defoliation while making active growth. Furthermore rest periods allow for a period of uninterrupted plant development so that the plants are provided with an opportunity to complete processes necessary for their survival and continued health, free from interference (Tainton, 1981).

2.12.5 Fires

According to Humphreys and Patridge (1995), burning native pastures gives better access to green feed, removes coarse less palatable herbage, stimulates new growth of grasses and thus maintains a balance between palatable and less palatable species, and ensures control of invading woody species. Tick control can also be a subsidiary benefit. A large enough area must be burned to prevent stock concentrating on the young shoots which are at a critical stage for damage (Humphreys and Patridge, 1995). According to Sombroek *et al.* (1993) maintaining high stocking pressure to maintain a leafy sward is the practice in most SNL which is an alternative to burning and is arguably more efficient in removing unpalatable material. In the Highveld with greater susceptibility for woody species development, occasional burns are likely to be beneficial to control bush encroachment. According to Sombroek *et al.* (1993) burning in winter does not damage the range and can be beneficial and also that sourveld grasses should be utilised in as young and nutritious state as possible.

Hodgkinson *et al.* (1984) states that fire is a natural phenomenon in rangelands and populations of all plant species are capable of surviving certain fire regimes. Though prescribed burning must be utilised where ignition of vegetation is done deliberately and subsequently the limits of the spread of the fire are controlled to achieve desired management objective.

2.12.6 Feed supplementation

Sourveld grasses become less palatable with age and as such animals may lose weight and condition. The limiting factor are protein and digestibility hence protein supplements improve the utilisation of winter pastures. According to Sombroek *et al.* (1993) in SNL the feed supplement takes the form of access to residues as an alternative feed supply and the use of purchased feed is extremely unusual. In the Highveld, being a sourveld, the livestock require feed supplements for about 4-6months if severe weight loss is to be prevented (Pitts, 1991). Sweetveld remains acceptable to stock throughout the year though it is important to select grazing to counteract the drop in protein and digestibility levels below maintenance requirements.

2.12.7 Types of ranges identified in Swaziland

2.12.7.1 Palatable (Sweetveld)

This occurs in the Lowveld of Swaziland region. It is most palatable and nutritious in summer and remains fairly palatable in winter. It has scattered trees and bushes including Acacia species. It provides for livestock throughout the year without need for supplementation.

2.12.7.2 Unpalatable (sourveld)

The Highveld of Swaziland, in which lies Motshane, Hawane, Nkhaba and Siphocosini has unpalatable rangelands. Thus the Highveld can be classified as a sourveld because of the high rainfall in the region and acidic soils (Sweet and Khumalo, 1994). During summer it produces fairly good quality grazing but during winter it is very low in feed value. Consequently livestock require supplementation for about 4-6months if severe weight loss is to be prevented. Unpalatable rangeland has a dense grass cover and is more tolerant of overgrazing than palatable rangeland (Pitts, 1991).

2.12.7.3 Mixed rangeland

This is an intermediate between palatable and unpalatable rangeland. It occurs in the Middleveld region. Supplements are required 3-4months in winter to prevent weight loss. According to a project released by the Lesotho's Ministry of Agriculture (1986), as much as there are many plants that cover the surfaces of rangelands, it is imperative to know the important ones -the indicators. They furnish both forage for animals and also information on the condition of the rangeland. Furthermore, the Lesotho's Ministry of Agriculture (1986), states three major plant groupings indicators fall into:

I. Desirables/Decreasers

These are grasses that are preferred by animals and are eaten first. They are the most desirable to have on a rangeland and their absence indicates some form of mismanagement. They are more in climax range and few in less fair and poor range.

II. Intermediates/Increasers

These plants increase with increasing grazing pressure. They are the next preferred to desirables. They are also found on climax range but are less desirable to livestock. They are very good indicators of range conditions as they tend to replace desirables as grazing pressure increases and become too heavy.

III. Undesirables/Invaders

These emerge when grazing pressure becomes too heavy for intermediates to handle. They are even least preferable to animals. They are usually present as shrubs, weeds, or annuals and they are highly unpalatable and do little to protect the soil. Thus they are in severe abundance in intensely overgrazed rangelands or those having some form of mismanagement.

According to Sweet and Khumalo (1994), Motshane, Hawane, Nkhaba and Siphocosini belong to vegetation class H2. This Highveld hill grassland has the following characteristic species of grasses: *Hyparrhenia hirta, Tristachya leucothrix, Themeda triandra, Loudetia simplex, Diheteropogon amplectens, Monocymbium ceresiiforme and Cymbopogon excavatus.* Rangeland degradation will be indicated by the increasing of *Eragrostis species and Sporobolus* species and associated species (Sweet and Khumalo, 1994).

2.13 Rangeland condition and diversity as indicator of rangeland condition

According to Miller (2007), vegetation diversity can be a useful indicator of the condition of the environment. Species diversity has been used for many years to monitor the environment and indicate changes in the state of the environment. The reason is that vegetation may vary in response to the usage of the rangeland, in their tolerability of activities that continue in the range, including the eating habits of the livestock. Thus we talk of decreasers and increasers. Furthermore, certain activities in the rangeland bring about the growth of certain species of vegetation. For instance with overgrazing, livestock intensity increases on the range beyond its carrying capacity (Sweet and Khumalo 1994).

CHAPTER 3

MATERIALS AND METHODS

3.1 Description of the study area

The study was conducted in four communal grazing areas (namely: Siphocosini, Nkhaba, Motshane and Hawane) in the Highveld of Swaziland. The Highveld of Swaziland lies at an altitude between 1000-1500m, topography being hilly to undulating with 10-30% slopes. The soils are very acidic loam and clays with rock outcrops. The area has more of a sub-tropical climate and receives an annual rainfall ranging from 850 to 1000 mm. The vegetation is classified as Highveld steep hill and mountain grassland (Sweet and Khumalo, 1994). The mean annual temperature varies between 12^{o}C and 20^{o}C (Monadjem and David, 2005). Granite is the main geological features, while gneiss, quartzite, lava are the dominant soil classes (Murdoch, 1970). The vegetation has been classified as short grassland with forest patches (Acocks, 1988).

3.2 Site selection and layout

Four rangelands were selected for this study. The selection criteria ensured general soil and vegetation homogeneity around the rangelands. Five transects (100m) were established at each of the selected rangelands in an anticipated direction of grazing activity evident. The five transects served as replicates.

3.3 Data collection

3.3.1 Grass species composition and dry matter production

Grass species composition was estimated from each 100 m transect using a point intercept method. The nearest plant and basal strikes were recorded from 100 point observations per transect. This sample size is adequate for detailed scientific studies in semi-arid savannas (Hardy and Walker, 1991). Point observations were spaced by approximately 1 m intervals and records were made over the length of transect in straight parallel lines. Vegetation survey was done in May 2011. For dry matter determination, grass shoots were harvested to stubble height from ten 0.25 m^2 quadrats laid under each transect. The harvested materials were dried to a constant weight at 72^{o}C and weighed to determine total dry matter (DM) yield.

3.3.2 Estimation of rangeland condition

Rangeland condition was estimated based on the dry matter yield and composition of palatable species (Barnes *et al*., 1984). Species were grouped into three palatability classes: highly palatable, moderately palatable and less palatable. Further, the ecological index method (EIM), (Vorster, 1982) was used to estimate the rangeland condition. To derive EIM, the grasses were categorised into ecological groups of decreaser, increaser IIa, increaser IIb and increaser IIc. Each class was given a relative index value, namely; decreaser = 10; increaser IIa = 7; increaser IIb = 4 and increaser IIc = 1. The percentage composition of grass species in each class was summed up, after which the sum for each class was multiplied by its relative index value. These amounts were totalled to give the condition index, which was divided into five ranges: very poor (100-280); poor (>280-460); fair (>460-640); good (>640-820) and excellent (>820).

3.3.3 Species identification and classification

Identification of plants was made in the field. For those species not identified, plants with full inflorescences and other vegetative parts were collected for further identification at Luyengo Campus and National Herbarium. Grasses were classified based on the succession theory described by Dyksterhuis (1949) and on the ecological information for the arid to semi-arid regions of South Africa (Tainton *et al*., 1980; Vorster, 1982). Accordingly, these species were grouped into (i) highly palatable species: those which occur in rangeland in good condition and decrease with over-grazing (decreasers), (ii) moderately palatable species: those which occur in rangeland in good condition and increase with moderate over-grazing (increaser iia), and (iii) less palatable species: those which occur in rangeland in good condition and increase with severe/extreme overgrazing (increasers iib and iic). In addition, species were grouped according to their life and growth forms.

3.3.4 Vegetation sampling and chemical analysis

Feed analysis was done for common grass samples collected in the different rangelands. Plant samples were analysed for Nitrogen (CP), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Phosphorus (P), Magnesium (Mg), Calcium (Ca), Potassium (K), Iron (Fe), Copper (Cu), Manganese (Mn) and Zinc (Zn). The NDF and ADF were determined by refluxing 2g plant samples with neutral detergent and acid detergent solutions, respectively, for 1 hour according to Van Soest *et al.* (1991). The NDF were assayed without sodium sulfite and α-amylase. Both NDF and ADF were expressed without residual ash. Nitrogen was determined by the Kjedahl method (AOAC, 1999, method no. 976.06). Phosphorous was analysed using the UltraViolet Spectrophotometer, K by flame photometer and Ca, Mg, Fe, Zn and Cu by atomic absorption spectrophotometer (Perkin-Elmer, 1982).

3.3.5 Soil sampling and analysis

Topsoil samples (to a depth of 20 cm) were taken from each transect at 10 random locations. Each set of 10 samples was bulked, thoroughly mixed, oven dried and passed through a 2 mm mesh screen pending analysis. Soil pH was measured in a 1:2.5 soil water relation extract method. The Kjeldahl method was used to determine percentage total N (Van Reeuwijk, 1992). Potassium was determined by emission spectroscopy, while Mg, Ca, Zn, Cu and Fe were determined by atomic absorption spectroscopy (Jackson, 1970). Phosphorous was detected by the ultra violet Spectrophotometer (Olsen and Sommers, 1982).

3.4 Data analysis

Herbaceous data as well as soil and vegetation nutrients among the rangelands were subjected to a one-way Analysis of Variance (ANOVA) following the General Linear Models procedure of SAS (1999). The means of the different rangelands were compared in terms of species composition, rangeland condition, bare patchiness, dry-matter yield soil and vegetation nutrients using the Duncan’s Multiple Range Test. For data that did not require analysis, simple descriptive statistics was employed.

CHAPTER 4

RESULTS

4.1 Grass layer

A total of 16 grass species were identified in the study area. Of these, 9 species were strong perennials and the remaining 7 were annuals. In addition, 5 species were identified as highly palatable, 6-moderately palatable and 4-less palatable species. The proportion of highly, moderately and less palatable grass species were significantly different ($P<0.05$) among the grazing areas. Hawane grazing area had the highest proportion of highly palatable species and Motshane had the lowest. Nkhaba had the largest proportion of moderately palatable species and Motshane-the lowest. Less palatable species had the highest frequency of occurrence in Motshane. Tables 2-5 show the life forms, desirability, ecological grouping and occurrence of grass species in the study areas.

Table 2. Life forms, desirability, ecological grouping and occurrence of grass species in Motshane rangeland.

Species	Life forms[1]	Palatability[2]	Ecological [3] value	Frequency
Eragrostis plana	Perennial	LP	inc II	32
Paspalum scrobiculatum	Weak perennial	MP	inc II	7.6
Grass like				15
Digitaria ternata	Annual	LP	inc II	16.2
Cynodon dactylon	Creeping	HP	inc II	1.6
Digitaria longiflora	Creeping	MP		0.2
Brachiaria brizantha	Perennial	MP	inc I	25.8
Hemarthria altissina	Creeping	HP	decreaser	1
Hyparrhenia filipendula	Perennial	MP	inc I	0.6

[1] A = annual, P = Perennial;
[2]HP - Highly palatable, MP = Moderately palatable, LP = Less palatable;
[3] De = Decreaser, Inc i = Increaser i, inc ii = Increaser iib;

Table 3. Life forms, desirability, ecological grouping and occurrence of grass species in Hawane rangeland.

Species	Life forms[1]	Palatability[2]	Ecological [3] value	Frequency
Digitaria diagonalis	Perennial	MP	inc I	10.8
Eragrostis plana	Perennial	LP	inc II	14.6
Paspalum scrobiculatum	Weak perennial	MP	inc II	8
Sporobolus fimbriatus	Perennial	HP	decreaser	3.4
Grass like				13.2
Themeda triandra	Perennial	HP	decreaser	21.2
Digitaria ternata	Annual	LP	inc II	22.2
Cynodon dactylon	Creeping	HP	inc II	2.4
Hyparrhenia filipendula	Perennial	MP	inc I	4.2
Aristida junciformis	Perennial	LP	inc III	0.2
Eragrostis curvula	Perennial	HP	inc II	0.4
Andropogon eucomus	Perennial	LP	inc II	0.4
Eragrostis chloromelas	Perennial	MP	inc II	0.2

[1] A = annual, P = Perennial;
[2]HP - Highly palatable, MP = Moderately palatable, LP = Less palatable;
[3] De = Decreaser, Inc i = Increaser i, inc ii = Increaser iib;

Table 4. Life forms, desirability, ecological grouping and occurrence of grass species in Nkhaba rangeland.

Species	Life forms[1]	Palatability[2]	Ecological [3] value	Frequency
Digitaria diagonalis	Perennial	MP	inc I	17.4
Eragrostis plana	Perennial	LP	inc II	18.2
Paspalum Scrobiculatum	Weak perennial	MP	inc II	23.2
Sporobolus fimbriatus	Perennial	HP	decreaser	10.4
Grass like				5
Themeda triandra	Perennial	HP	decreaser	1.4
Digitaria ternata	Annual	LP	inc II	24.2
Cynodon dactylon	Creeping	HP	inc II	0.2

[1] A = annual, P = Perennial;
[2]HP - Highly palatable, MP = Moderately palatable, LP = Less palatable;
[3] De = Decreaser, Inc i = Increaser i, inc ii = Increaser iib;

Table 5. Life forms, desirability, ecological grouping and occurrence of grass species in Siphocosini rangeland.

Species	Life forms[1]	Palatability[2]	Ecological[3] value	Frequency
Themeda triandra	Perennial	HP	decreaser	21.2
Digitaria ternata	Annual	LP	inc II	22.2
Grass like				13.2
Digitaria diagonalis	Perennial	MP	inc I	10.8
Eragrostis plana	Perennial	LP	inc II	14.6
Paspalum scrobiculatum	Weak perennial	MP	inc II	8
Sporobolus fimbriatus	Perennial	HP	decreaser	3.4
Cynodon dactylon	Creeping	HP	inc II	2.4
Hyparrhenia filipendula	Perennial	MP	inc I	4.2
Aristida junciformis	Perennial	LP	inc III	0.2
Eragrostis curvula	Perennial	HP	inc II	0.4
Andropogon eucomus	Perennial	LP	inc II	0.4
Eragrostis chloromelas	Perennial	MP	inc II	0.2

[1] A = annual, P = Perennial;
[2]HP - Highly palatable, MP = Moderately palatable, LP = Less palatable;
[3] De = Decreaser, Inc i = Increaser i, inc ii = Increaser iib;

Table 6. Rangeland condition based on the ecological index method for each site.

Ecological values						
Rangeland	**Decreaser**	**Increaser IIa**	**Increaser IIb**	**Increaser IIc**	**Total index**	**Condition**
Motshane	10	184.8	229.6	0	424.4	Fair
Hawane	246	105	192.8	0.2	544.0	Fair
Nkhaba	118	121.8	263.2	0	503.0	Fair
Siphocosini	246	105	192.8	0.2	544.0	Fair

4.2 Soil nutrients

Results on soil pH, macro and micro elements are presented in Table 7 and 8. Soil pH ranged between 4.3-4.98 and showed little variability among the rangelands. Soil N had the highest value of 0.13% in Siphocosini and a value of 0.11% in Motshane. The Ca content varied between 1.4 cmolc Kg^{-1} (Motshane) and 4.28 cmolc Kg^{-1} (Siphocosini). The level of Mg was significantly different ($p<0.05$) among the grazing areas with the highest value of 5.73 cmolc Kg^{-1} recorded in Hawane and the lowest value of 2.32 cmolc Kg^{-1}-recorded in Motshane. Potassium content showed significant differences among the grazing areas (range: 0.12-1.11 cmolc Kg^{-1}). Motshane rangeland had the highest P (mg Kg^{-1}). There were significant differences ($p<0.05$) in Zn and Cu contents between the grazing areas.

Table 7. Soil pH, nitrogen (N) and macro elements (Mean ± SE cmolc Kg^{-1}) of top soil sampled from the rangelands.

Rangeland	Soil pH	N%	Ca	Mg	K
Siphocosini	4.56^{a}±0.18	0.13^{a} ±0.01	4.28^{a} ±0.37	3.6^{bc} ±0.57	0.53^{ab} ±0.13
Hawane	4.77^{a} ±0.18	0.12^{ba} ±0.01	1.09^{e} ±0.37	5.73^{a} ±0.57	1.11^{e} ±0.13
Nkhaba	4.98^{a} ±0.18	0.12^{ba} ±0.01	1.99^{cd} ±0.37	4.52^{b} ±0.57	0.12^{d} ±0.13
Motshane	4.3^{a}±0.18	0.11^{cb}±0.01	1.4^{d} ±0.37	2.32^{d} ±0.57	0.25^{c} ±0.13

Means in the same column with different superscripts are significantly different (P<0.05)

Table 8. Soil micro elements (Mean ± SE) and phosphorous content of top soil sampled from the rangelands.

Rangeland	Zn(ppm)	Cu(ppm)	P(mg/Kg)
Siphocosini	5.79^{bcd} ±0.97	6.43^{cd} ±1.39	1.46^{c} ±1.55
Hawane	13.2^{a} ±0.97	6.05^{cd}±1.39	3.08^{b} ±1.55
Nkhaba	3.6^{cd} ±0.97	9.97^{b} ±1.39	3.29^{b} ±1.55
Motshane	6.69^{bde}±0.97	10.6^{a} ±1.39	4.1^{a} ±1.55

Means in the same column with different superscripts are significantly different (P<0.05)

4.3 Composition of common grass species

Common grass species in the current study represents those species that were recorded in the four rangelands and with an average frequency of occurrence exceeding 10%. This was based on the average of the four rangelands. Averages were *Eragrostis plana*

(19.85%), *Digitaria ternata* (21.2%), *Paspalum scrobiculatum* (11.7%) and g*rass like plant* (11.6%) respectively. Based on this definition, only 4 grass species were regarded as common out of the 16 species. Two species (*Eragrostis plana* and *Digitaria ternata)* are less palatable, while *Paspalum scrobiculatum* is moderately palatable. *Eragrostis plana* and *Digitaria ternata* were recorded in Motshane, Hawane, Nkhaba and Siphocosini. The same applies to *Paspalum scrobiculatum* and g*rass like plant*. Table 9 and figures 2 - 5 show the frequency of the common grass species in the rangelands.

Table 9. Frequency of common grasses in the four rangelands.

Rangeland	Frequency of Occurrence %			
	Digitaria ternata	*Paspalum scrobiculatum*	*Eragrostis plana*	*Grass like*
Siphocosini	$22.2^{a} \pm 2.76$	$8.0^{a} \pm 4.49$	$14.6^{a} \pm 2.76$	$13.2^{a} \pm 2.78$
Hawane	$22.2^{a} \pm 2.76$	$8.0^{a} \pm 4.49$	$14.6^{a} \pm 2.76$	$13.2^{a} \pm 2.78$
Nkhaba	$24.2^{a} \pm 2.76$	$23.2^{d} \pm 4.49$	$18.2^{a} \pm 2.76$	$5^{b} \pm 2.78$
Motshane	$16.2^{a} \pm 2.76$	$7.2^{cb} \pm 4.49$	$32^{a} \pm 2.76$	$15^{a} \pm 2.78$

Means in the same column with different superscripts are significantly different (P<0.05)

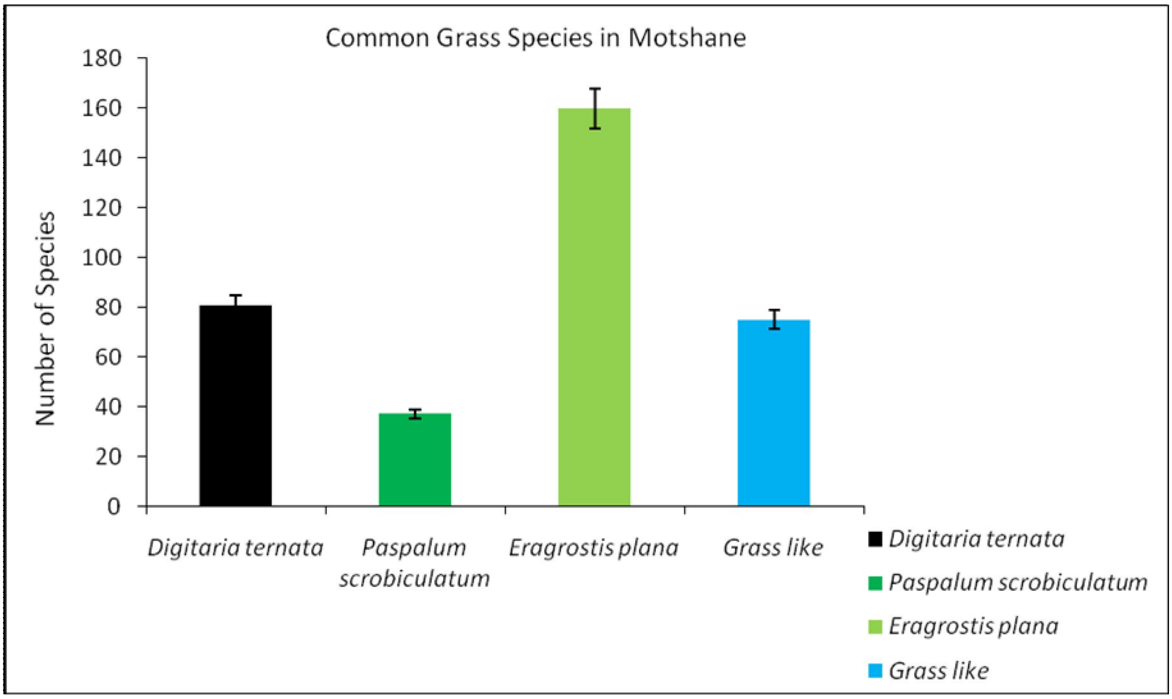

Figure 2. Graph showing the frequency of common grass species in Motshane

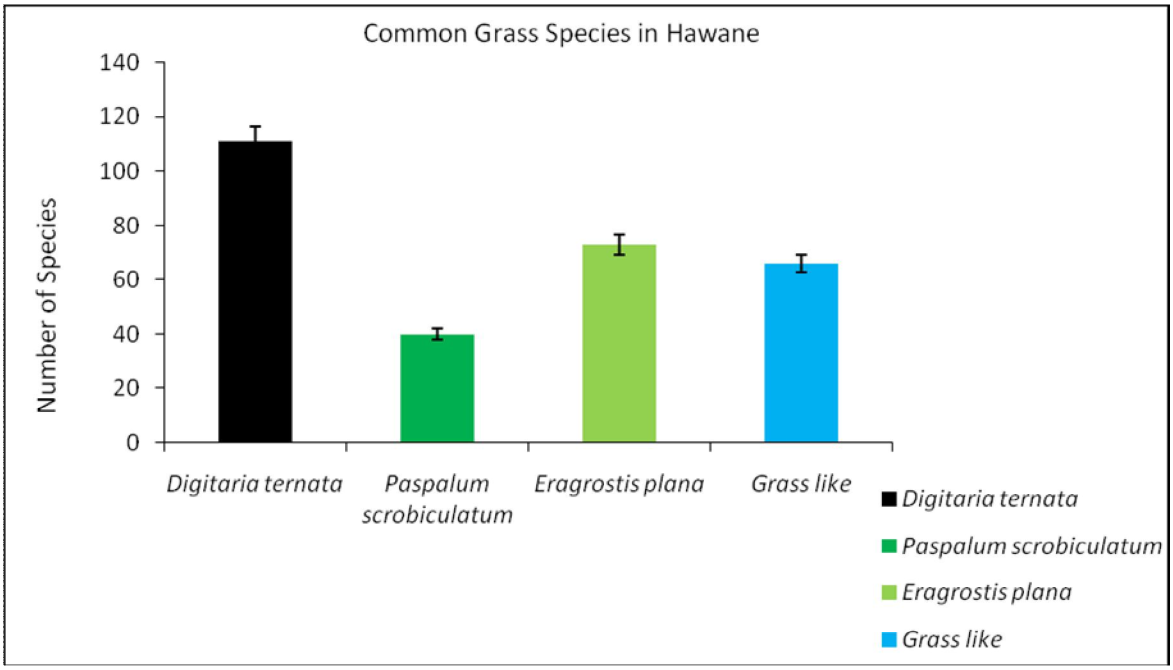

Figure 3. Graph showing the frequency of common grass species in Hawane

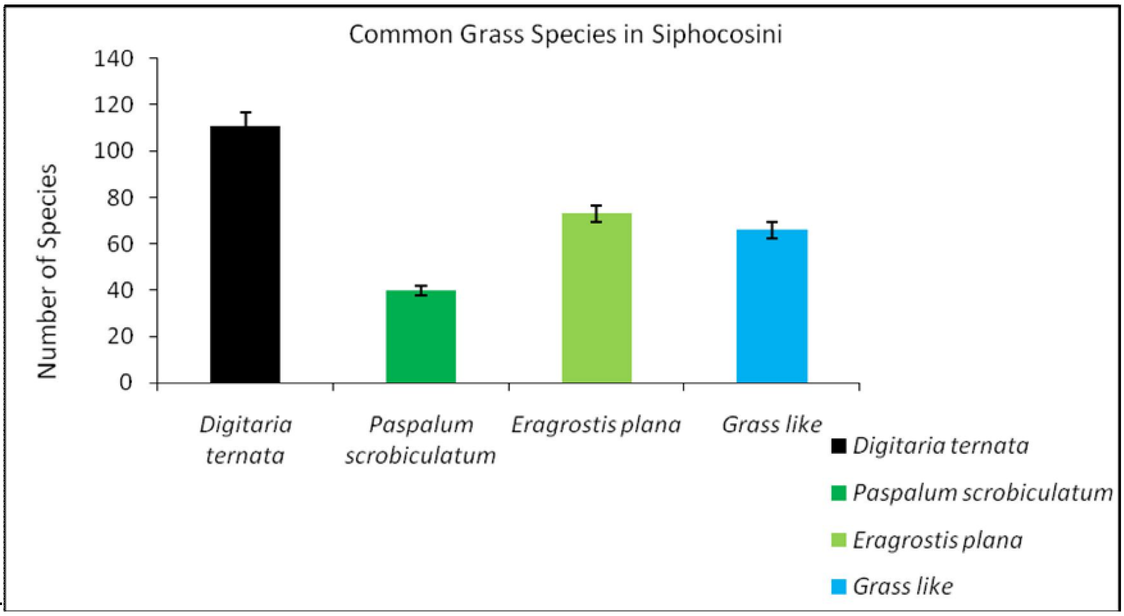

Figure 4. Graph showing the frequency of common grass species in Siphocosini

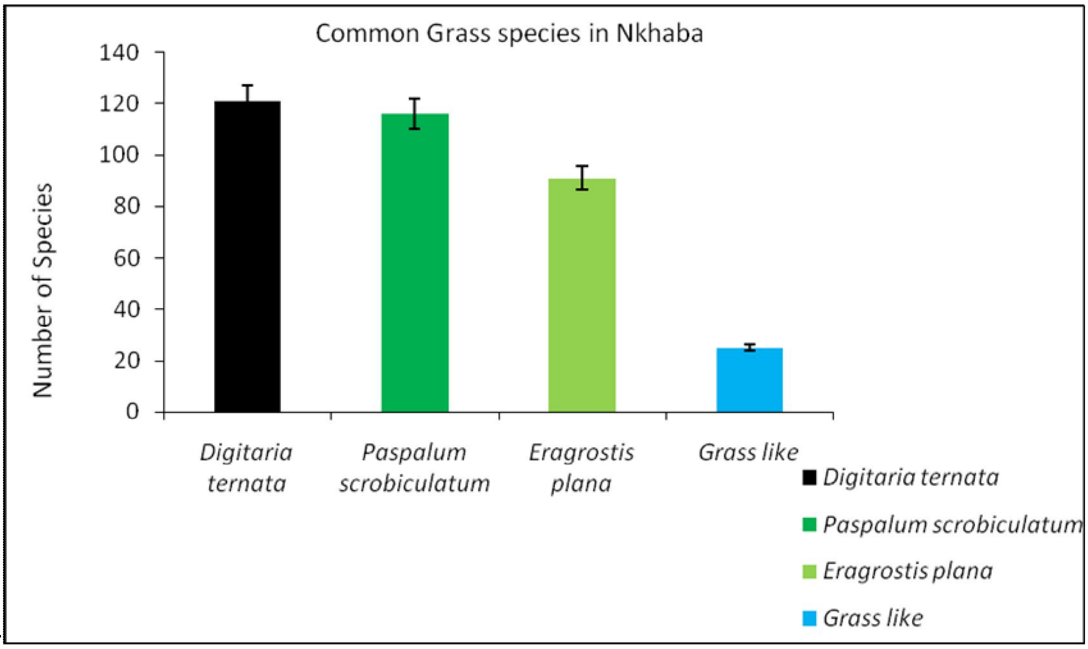

Figure 5. Graph showing the frequency of common grass species in Nkhaba

4.4 Life forms of herbaceous layer

Significant differences (P<0.05) were observed in the frequency of annual and perennial grasses among the rangelands (Table 10). The proportion of annual grass species was greatest (P<0.05) at Nkhaba grazing area (24.2%) and lowest at Motshane (16.2%). Nkhaba (70.6%) had the highest percentage of perennials and Hawane (63.4%)-the lowest. The Highveld has high proportion of perennials (65.85%) than annuals (21.2%).

4.5 Dry matter yield and bare patchiness

Dry matter yield ranged from 246.2 kg/ha to 432.2 kg/ha (Table 10). Motshane, Siphocosini and Nkhaba were not different (p>0.05) in dry matter yield production. Hawane had the lowest dry matter yield when compared to the other three rangeland areas. The frequency of bare patchiness was significantly different (P<0.05) among the rangelands with the highest value of 15.1% obtained in Siphocosini and the lowest of 1.93 in Nkhaba. On average the Highveld has 9.34% of bare land which shows rangeland degradation (Table 10).

Table 10. Frequency of life forms, bare patchiness and dry matter yield (DM) of the herbaceous layer in the rangelands.

Rangeland	Frequency of Occurrence %			DM Kg/ha
	Annual grass	Perennial grass	Bare patchiness	Grass
Siphocosini	22.2^{a} ±3.2	63.4^{c} ±4.8	15.1^{ab} ±3.7	432.2±21.1
Hawane	22.2^{a} ±3.2	63.4^{c} ±4.8	9.72^{bc} ±3.7	246.2±21.1
Nkhaba	24.2^{a} ±3.2	70.6^{a} ±4.8	1.93^{d} ±3.7	319.4±21.1
Motshane	16.2^{b} ±3.2	66^{b} ±4.8	10.6^{ab}±3.7	419.8±21.1

Means in the same column with different superscripts are significantly different (P<0.05)

4.6 Plant nutrients

Results of the nutrient contents of grasses harvested from the study areas are presented in Table 11 and 12. Grasses collected from the rangelands were not different (P>0.05) in levels of Ca, Mg, K, P and Fe. Trace elements (Mn and Zn) were not different (P>0.05) among the grass samples collected from the rangelands. There were no clear trends of variations in the macro and micro contents of grasses collected from the rangelands.

Table 11. Chemical composition (%) of common grass samples harvested from the four rangelands.

Plant Nutrients					
Rangeland	Ca	Mg	K	P	Fe
Siphocosini	0.18^{ad} ±0.02	0.23^{cd} ±0.03	2.45^{b} ±0.22	0.17^{c}±0.04	0.19^{ab} ±0.03
Hawane	0.22^{ac} ±0.02	0.27^{abc} ±0.03	2.32^{c} ±0.22	0.24^{ab} ±0.04	0.21^{a} ±0.03
Nkhaba	0.18^{ad} ±0.02	0.3^{ab} ±0.03	2.07^{d} ±0.22	0.21^{bc} ±0.04	0.17^{abc} ±0.03
Motshane	0.31^{a} ±0.02	0.31^{a} ±0.03	2.83^{a} ±0.22	0.18^{c}±0.04	0.14^{bcd} ±0.03

Means in the same column with different superscripts are significantly different (P<0.05)

Table 12. Crude protein and fibre contents (%) of common grass samples harvested from the four rangelands.

Plant Nutrients					
Rangeland	CP	ADF	NDF	Mn	Zn
Siphocosini	5.96^{cd} ±0.77	29.76^{a} ±1.97	62.79^{a} ±2.57	0.005	0.01
Hawane	7.05^{a} ±0.77	28.03^{a} ±1.97	52.01^{a} ±2.57	0.007	0.01
Nkhaba	5.55^{e} ±0.77	29.36^{a}±1.97	51.65^{a} ±2.57	0.002	0.01
Motshane	6.33^{bcd} ±0.77	27.03^{a} ±1.97	51.65^{a}±2.57	0.004	0.01

Means in the same column with different superscripts are significantly different (P<0.05)

4.7 Stocking rate and rangeland condition

Dry matter yield of grasses in the current study was within the range of 246.2 Kg ha^{-1} to 432.2 Kg ha^{-1}. This gave an average yield of 354.4 Kg ha^{-1}. According to MOA (2010), 5 604 animals graze on these rangelands. These rangelands have a total area of 2 000 Ha. This gave a stocking rate of 0.4 HA/LSU. The study gave an average condition index of 503.85, which falls within the range of (460-640) and this according to Vorster (1982) is fair. Table 6 shows the rangeland condition for the different rangelands based on the ecological index method.

CHAPTER 5

DISCUSSIONS

5.1 Soil analysis

Soil pH found in this study ranged from 4.3 to 4.98 and there were no differences ($p>0.05$) among the rangelands. These results are in agreement with the report of previous studies conducted by Murdoch (1970), Sutcliffe (1975). Soil analysis explained the existence of significant variations in the levels of macro and micro nutrients among the rangelands. Complex spatial patterns of soil nutrients in rangelands have been commonly presumed to develop over time as a result of interactions of animal activities, climate, parental material, vegetation type, and topography (Wang *et al*., 2001; Nsinamwa *et al*., 2005; Solomon *et al*., 2007a,b). Variations in grazing pressure and history and their effects on plant and litter cover, and on soil structure and fertility were reported by Robertson *et al*. (1997); Snyman and du Preez (2005), Smet and Ward (2006), and Solomon *et al*. (2007a). Several studies reported that increase in grass cover has been associated with increases in the concentration of soil nutrients.

One prerequisite for sustainable land use is to maintain or improve the soil nutrients since deterioration below critical point makes restoration a slow process or even impractical. In view of this, the present study indicated that though all macro nutrients were generally regarded as low, Mg and K (also Zn and Cu) could maintain the minimum requirements for plant growth, while the level of Ca, P and N were below the requirement for plant growth against Ca-3%, P-0.4% and N-2%, (McLaren *et al*., 1997). There is ample evidence to show that N and P deficiency are common occurrence in savannah rangelands (Jun *et al*., 2001; Solomon *et al*., 2007a,b), and this severely limits the yield of herbaceous layer. All the findings in the soil analysis suggested that the data are notable for lack of regular pattern of variability among the rangelands.

5.2 Grass layer

A substantial number of grass species were identified in the current study. Taking all the study sites together there were more perennial grass species (11) than annual species (1). There were 3 creeping grass species. One grass like species could not be classed in any life-form. Likewise, in terms of frequency of occurrence, perennials were more abundant than annuals in all the rangelands. However, the occurrence of each life form varied greatly among the rangelands. Nkhaba had the highest (24.2%) and Motshane had the lowest (16.2%) proportion of annuals, respectively. The existence of variation in the frequency of life forms, particularly in the proportion of perennials may elucidate variation in stocking rates or nature of soil or a combination of both. Nevertheless, determination of the stocking rates of the study area has been documented, and was based on the winter season and therefore this requires future research attention, so that all seasons are covered.

Rangelands are ecologically favoured when perennials dominate the ecosystem. In semi-arid savannahs, perennial grasses give better indication of the health status of rangelands than annuals. Perennials yield higher dry matter and provide better soil protection than annuals, Van Wyk (1999). When all rangelands are combined, the number of moderately palatable grass species recorded was highest (6) followed by highly palatable (5) species. Four (4) species were recorded to be less palatable.

In terms of frequency of occurrence, the proportion of highly palatable species was highest in Hawane than the other rangelands. Nkhaba, Hawane and Motshane had some moderately palatable species. Common grass species in the rangelands were found to be less palatable. In summary, it is important to note that classification of species into palatability groups relied most importantly on the merits of species with respect to life forms and desirability. However, this classification has its own limitation, when desirability is taken as one palatability criteria because in the absence of good forage species, the hardly preferred grasses can be grazed and therefore be considered as palatable.

5.3 Common grass species

Only four grass species (*Eragrostis plana*, *Digitaria ternata, Paspalum scrobiculatum and grass like species*) were regarded as common throughout most of the study areas. This was a first study of its kind in the Highveld and so could not be compared with any other previous studies. *Paspalum scrobiculatum* was reported as important forage species for animal production in southeast Queensland, Australia (Skerman *et al*., 1990). It is very palatable and highly digestible during summer, retains these characteristics later into maturity than other grasses. It has low crude protein level as it was recorded by Skerman *et al*. (1990).

Eragrostis plana is the dominant key species in rangelands that are severely overgrazed in the grassland biome of South Africa. Van Wyk (1999) mentions that it is generally a poor grazing grass, but is utilised late in the season in the more arid parts, possibly because the leaves remain green until late in autumn. *Digitaria ternata* was also found to be common in the rangelands. According to Van Wyk (1999), it has a low grazing value. It is a palatable grass that seems to be utilised, but delivers a very low leaf production. This species occurs over the entire African continent (with the exception of North Africa), as well as in Asia, the Far East and Australia.

Grass like species was also recorded as common in the four rangelands. It was found to be fully utilised by livestock in all rangelands. There was no much literature on its attributes as far as nutritive value is concerned. During this study, it was noted that it grows near swampy areas. Results of this study confirm the findings of other studies (Annika, 2000; Smet and Ward, 2005; Solomon *et al*., 2007a) in demonstrating that variations in grazing pressure and history could be the primary factor that influence the composition of grasses in semi-arid rangelands of Africa. Other factors such as rainfall, topography and soil type could also be regarded as secondary factors that affect species composition of grasses in the semi-arid rangelands.

The study showed that some strong highly palatable species (e.g. *Sporobolus fimbriatus*, *Themeda triandra* and *Eragrostis curvula*) that produce large quantity of leaf biomass occurred in low frequency and distribution in the rangelands. This suggests that such grass species which annually produce small amount of large sized, poorly dispersed seeds can gradually disappear under continuous heavy grazing practised in communal lands that are already subject to recurrent drought, and therefore, these species require *in situ* conservation.

5.4 Dry matter yield and bare patchiness

Dry matter yield of grasses in the current study was within the range of 246.2 Kg ha^{-1} - 432.2 Kg ha^{-1}. The results in the current study suggest that with continuous higher stocking rates and grazing pressure on communal lands, the above ground biomass grass production is low, both because of heavy utilisation and destruction of grass roots by trampling livestock (Quinfeng *et al*., 1999). Consequently, the production capacity of grasses and their ultimate contribution to the total dry matter yield were reduced.

The percentage of bare ground showed significant differences ($p<0.05$) among rangelands and ranged from 1.93 to 15.9. This value reflects the existence of high bare ground in most of the study areas which is an indication of rangeland degradation. Solomon *et al*. (2007a, b) reported that bare ground was more common in communal lands that are subject to high grazing pressure over long time.

5.5 Stocking rate and rangeland condition

The study showed a stocking rate of 0.4 Ha/LSU which is extreme overstocking. According to Sweet and Khumalo (1994), the stocking rate of the Highveld is 3-4 Ha/LSU and this shows that the rangelands are overstocked. It is essential and crucial to know the stocking rate of a particular area. This helps in fodder flow planning (Mpofu, 2010). As grasses diminish in a rangeland, a rangeland user has to know as to how to cater for the animals as a form of supplementation. These are very important aspects of fodder flow. Visual observations showed that rangelands of the Highveld are shrinking. This was seen by the mushrooming of homesteads into the range and also the construction of dip tanks. Interviews with community members also showed that people have no information about the utilisation of rangelands and also the importance of knowing their status, type of grass species and their contribution to our livestock.

The rangeland condition was found to be fair, according to ECI by Vorster (1982). One can agree with the method as most of the studied rangelands had a mixture of palatable and less palatable species. It was also observed that most of the livestock utilised the less palatable species as most of the palatable ones are diminishing or not there at all.

Another important aspect is vegetation diversity. This refers to the number of different vegetation classes or types in an ecosystem (Mapaure, 2010). This means that the more vegetation types in that ecosystem, the higher the vegetation diversity. The study showed that vegetation diversity in the Highveld of Swaziland is high. This is so because, from four (4) rangelands, a total of 16 grass species were found against seven which are characteristic of the Highveld hill (Sweet and Khumalo, 1994).

5.6 Plant nutrients

Crude protein value ranged between 5 and 7% and showed an average of 6% among the rangelands. This showed a low value. According to Skerman *et al.* (1990), most plants show low nutrient values in winter. It was below animal requirement. The levels of plant Ca, P and Zn were below the animal requirement for maintenance against Ca-4.8%, P-2.8% and Zn-0.04% while Mg levels fell within the requirement range in similar ecosystems of Southern Africa (Skerman *et al.* 1990). ADF and NDF values were not different (P>0.05) among the rangelands. According to Skerman *et al.* (1990), NDF values are high in the late growing season as plants are mature and they agreed with the current study. Digestibility of forages is low in the late growing season.

5.7 Practical application and implications

Results of this study show that rangelands of the Highveld of Swaziland are degraded. This is probably due to the high stocking rate, that is, 0.4 HA/LSU versus the recommended stocking rate of 3-4 HA/LSU. If this problem is not addressed quickly, this agro-ecological zone will suffer economic loss due to poor livestock productivity. Livestock farmers need to reduce livestock numbers, adopt light grazing pressure; there is a need for rehabilitation programmes in particular range reseeding to restore the lost palatable species. Such programmes will require evaluation of the available methods and practices that can be simple and cost effective as well as workable with the knowledge and participation of the communal people.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

Based on the findings of this study, it was concluded that vegetation diversity in the study area was high. There were more grass species than expected. Sixteen grass species (nine strong perennials and seven annuals) were identified. Secondly stocking rate was found to be 0.4 HA/LSU which shows that rangelands of the Highveld are severely overstocked. Grass species that were identified as commonly occurring in this study were all indicators of grazing disturbance but *P. scrobicutilum* have moderate palatability. On the other hand, some valuable grass species (*Sporobolus fimbriatus*, *Themeda triandra*, *Hemarthria altissina* and *Eragrostis curvula*) were poorly represented in the species composition demonstrating that they are more prone to extinction, and hence may receive concern for *in situ* conservation. Thirdly the rangeland condition was found to be fair, according to the ecological condition index method (ECI).

Most soil nutrients were found to be generally low, but there have not been reports to show whether or not this is related to range condition. The levels of plant Ca, P and Zn were below animal requirement for maintenance, while Mg levels fell within the requirement range in similar ecosystems of Southern Africa. Most of plant nutrients were found to be low. The reason was that the study was carried out at the end of the growing season where plants are mature and thus less nutritious.

Finally, it can be concluded that species composition, bare ground, grass DM yield and cover can serve as indicators to explain the state of health of rangelands. Severe rangeland degradation was observed in some rangelands in form of extensive bare ground (visual observation).

6.2 Recommendations

Severe rangeland degradation was observed in some rangelands in form of extensive bare ground (visual observation) and dominance of less palatable species. Therefore, rangeland rehabilitation programme should be initiated giving priority to those that are most seriously affected for example Siphocosini. Initially, the rehabilitation programme requires evaluation of the available methods and practices that can be simple and cost effective as well as workable with the knowledge and participation of the communal people. The study showed that some strong highly palatable species (e.g. *Sporobolus fimbriatus*, *Themeda triandra* and *Eragrostis curvula*) that produce large quantity of leaf biomass occurred in low frequency and distribution in the rangelands. This suggests that such grass species which annually produce small amount of large sized, poorly dispersed seeds can gradually disappear under continuous heavy grazing practised in communal lands that are already subject to recurrent drought, and therefore, these species require *in situ* conservation. There is a need to sensitise rangeland users in the Highveld to reduce pressure on these rangelands by encouraging them to venture into feedlotting or take their animals to sisa ranches. Indeed, future studies are required to establish the effects of soil and plant nutrients on the performance of grazing animals. There is also a need for further research to see the range trend in relation to stocking rates for all seasons.

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APPENDICES

A. Summary of ANOVA

PLANT NUTRIENTS

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	4	0.89	0.2225	0.003758		
Column 2	4	1.11	0.2775	0.001292		
Column 3	4	9.67	2.4175	0.100492		
Column 4	4	0.8	0.2	0.001		
Column 5	4	0.71	0.1775	0.000892		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	15.48368	4	3.87092	180.1545	1.75E-12	3.055568
Within Groups	0.3223	15	0.021487			
Total	15.80598	19				

SOIL NUTRIENTS

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Column 1	4	24.89	6.2225	0.405825		
Column 2	4	114.18	28.545	1.566967		
Column 3	4	218.1	54.525	30.3889		
Column 4	4	0.018	0.0045	4.33E-06		
Column 5	4	0.04	0.01	0		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8925.457	4	2231.364	344.7539	1.46E-14	3.055568
Within Groups	97.08509	15	6.472339			
Total	9022.542	19				

B. Estimation of rangeland condition

1. Calculation of ecological index method (EIM), by Vosrster (1982).

To derive EIM, grasses are categorised into ecological groups of decreaser, increaser IIa, increaser IIb and increaser IIc. Each class is given a relative index value namely; decreaser = 10; increaser IIa = 7; increaser IIb = 4 and increaser IIc = 1.

The percentage composition of grass species in each class was summed up and multiplied by its relative index value.

The sums give condition indexes with five ranges:

Very poor (100-280); poor (280-460); fair (460-640); good (640-820); and excellent (>820).

C. Common and scientific names of grasses identified in the study area

Scientific Name	**Common name**
Digitaria diagonalis	*Brown-seed Finger Grass*
Eragrostis plana	*Tough Love Grass*
Paspalum scrobiculatum	*Veld Paspalum*
Sporobolus fimbriatus	*Dropseed Grass*
Themeda triandra	*Red Grass*
Digitaria ternata	*Black-seed Finger Grass*
Cynodon dactylon	*Couch Grass*
Digitaria longiflora	*False Couch Grass*
Brachiaria brizantha	*Common Signal Grass*
Hemarthria altissina	*Swamp Couch*
Hyparrhenia filipendula	*Fine Thatching Grass*
Aristida juciformis	*Gongoni Three-awn*
Eragrostis curvula	*Weeping Love Grass*
Andropogon eucomus	*Snowflake Grass*
Eragrostis chloromelas	*(Narrow) Curly Leaf*

D. PICTURES FROM SAMPLING SITES

Figure 1. Cattle grazing at Motshane rangeland

Figure 2. Researcher carrying out the point-intercept method

Figure 3. Researcher collecting grass samples for analysis

Figure 4. A stand of *Digitaria ternata* at Hawane rangeland

Figure 5. Cattle grazing at Hawane rangeland

Figure 6. A view of Nkhaba rangeland

Figure 7. A stand of *Eragrostis plana* at Nkhaba rangeland

Figure 8. A view of Motshane rangeland

Figure 9. Researcher collecting soil samples

Figure 10. Researcher conducting analysis in a laboratory