Vegetation and soil characteristics around water points under three land management systems in semi-arid rangelands of the Eastern Cape, South Africa

By

Siyabulela SIMANGA

(200701551)

A Dissertation Submitted to the Faculty of Science and Agriculture in Partial Fulfillment of the Requirements of the degree of

MASTER OF SCIENCE IN AGRICULTURE PASTURE SCIENCE

Department of Livestock and Pasture Science

Faculty of Science and Agriculture

University of Fort Hare

Supervisor : Prof. ST Beyene

Co-Supervisor : Prof. IC Wakindiki

Co-Supervisor : Dr. K. Mopipi

December 2013

DECLARATION

I declare that the dissertation titled VEGETATION AND SOIL CHARACTERSICS AROUND WATER POINTS UNDER THE THREE LAND MANAGEMENT SYSTEMS IN SEMI-ARID RANGELANDS OF EASTERN CAPE, SOUTH AFRICA is my own work, and has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete reference.

________________________ ________________________

Mr. Siyabulela Simanga **Date**

Approved for style and content by:

____

Prof. S.T. Beyene

(Supervisor)

____

Prof. I.C. Wakindiki

(Co-Supervisor)

____

Dr. K. Mopipi

(Co-Supervisor)

December 2013

PREFACE

This dissertation consists of six chapters. Chapter one provides the background, justification and objectives of the study. Chapter two gives a general review of the literature relevant to the study. Chapter three, four and five covers the materials and methods used in this study and reports the findings (results) of the study. Chapter six covers general discussion of results, conclusions and recommendations for further studies.

Vegetation and soil characteristics around water points under three land management systems in semi-arid rangelands of the Eastern Cape, South Africa

ABSTRACT

This study investigated the vegetation and soil characteristics in relation to distance from water points under different land management systems in semi-arid rangelands of South Africa. Six study sites, two each from communal grazing, commercial farming and game reserves were selected. Two watering points were selected in each study site. Two 500 m transects were laid from the selected watering points. Each transect was divided into sub-transects at 25 m, 50m, 100m, 200m, 300m and 500m from water points. A 100 m^2 plot was marked in each sub-transect to record grass biomas, species composition, structure and distribution of woody vegetation and physical and chemical soil properties. Data were collected for two seasons 2012/13 (winter and summer). Thirty and 41 grass and woody species respectively were identified in all study areas. The most common and dominating grass species include *Cynodon dactylon*, *Digitaria eriantha*, *Eragrostis obtusa*, *Setaria sphacelata* and *Sporobolus fimbriatus*. *Cynodon dactylon* and *S. sphacelata* occurred more abundantly ($p < 0.05$) in the game reserves than in the other land management catergories. All the grass species had similar ($p > 0.05$) abundance along distance gradient from water points. Grass dry matter (GDM) showed significant differences ($p < 0.05$) between and within land management systems. However, GDM was not significantly affected by season, location of water point within each farm or reserve and distance along water points. *Acacia karoo, Coddia rudis* and *Ehretia rigida* were the most dominant woody species. Tree equivalent (TE) density of all encroaching woody plants combined was significantly ($p < 0.05$) higher on the communal area (1732 TE ha^{-1}) than the commercial ranches (1136 TE ha^-

^{1}) and game reserves (857 TE ha^{-1}), but with no marked variations along distance from water points under all the land management systems. The electric conductivity (EC) was significantly ($P < 0.01$) higher in game reserves than in communal grazing areas and ranches. Soil organic matter percentage showed greatest and lowest values in the game reserves and commercial respectively.

Soil pH and bulk density did not vary but soil organic matter (SOM), EC, bulk density and soil compaction were significant different with no increasing or decreasing trends. Soil properties were affected by herbivore pressure and trampling around water points with inconsistence magnitude and direction. In conclusion, grass species composition and GDM did not respond to distance from water points because either grazing gradient was absent or the length of transects was not enough to explain the absence or presence of gradients. High proportion of *A. karoo* and high densities of seedlings and saplings would seem as very good indicators of the woody vegetation changes in the different land management systems and distance from water points. The soil quality indicators around the water-points showed that livestock and game affected soil parameters.

Key words: Grass yield, tree density, woody encroachment, trampling, soil bulk density

DEDICATION

This thesis is dedicated to my father **Pasile Wilson Simanga**, my late mother (Nosiseko Simanga), my daughter **Ahlumile-Inako** and the rest of the **Simanga** family.

ACKNOWLEDGEMENTS

I would like to give praise to the Almighty God, for the life he has given unto me. The contributions of the following individuals and organizations to this study are gratefully acknowledged:

My heartfelt thanks go to Prof. Solomon T. Beyene for his supervision and support in this study. Sincere thanks go to Prof. Isaiah Wakindiki for his professional support and advice on soil analysis and Dr. Keletso Mopipi (Co-supervisors). It has been an honour to share this time with them. Sincere and humble thanks are due to Upper Gqumashe and Kwezana community, Mr Glen-Muir, Honeydale research farm manager and Eastern Cape Parks and Tourism Agency for allowing this research to be conducted in their farms. Many special thanks go towards Mr. Monwabisi W. Sibanga (Bra Willie), Mr. Mweli Nyanga (Bra Mawawa) and Dumisani Pepe (Bra Dumza) for their patience, friendship and technical assistance during data collection. I would specifically like to thank the department of Livestock and Pasture Science for provision of laboratories, equipment and vehicles.

I also extend my special thanks to University Fort Hare postgraduates and undergraduate students due to their skill formed the backbone of the data collection. Special mention is hereby extended to Andiswa Zweni, Vuyisa A. Hlathini, Mango Mandilakhe, Vuyolwethu Ngcongolo, Siviwe Feketshane, Siphamandla Bouga Huza, Siviwe Hermanus, Mjelo Gcobani, Lizwel Maphumo, Vuyokazi Sikhundla, Bukho Gusha, Cebisa Kumanda, Libala Nothiswa and Busisiwe Gunya. Further gratitude goes to Ms Noluvuyo Moko (Sis Vovo) for her support in printing my data sheets and Adonis Nciiza for his support in soil analysis. A special word of thanks goes to Dr. Mota Lesoli and friends/colleagues Mr. Masibonge Gxasheka, Mr. Kwaza Ayanda, Mr. Soga Sizwe and Mr. Nkohla B. Msimelelo for their support and sharing hard moments with me. Finally, my heartfelt gratitude goes out to my family for their enduring strength and support, for believing in me and more importantly for being there to reassure me of God’s mercies, whenever the going was tough: Pasile Wilson Simanga (father), Nomthunzi Simanga (stepmother), Lonwabo and Luvuyo (brothers) and Abongile, Sinoxolo and Sihle (sisters), Ahlumile-Inako (daughter), and especially my late mother (Nosiseko Simanga); their prayers, sacrifices, love, and support have been the driving force behind me. I am eternally grateful to all of you.

I am sincerely grateful to the National Research Foundation (NRF) of South Africa for their Scarce-Skill grant and the Govan Mbeki Research and Development Center (GMRDC) of the University of Fort Hare for funding this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
ASL	Above Sea Level
DM	Dry Matter
EC	Electrical Conductivity
EIM	Ecological Index Method
g/cm3	Grams/cubic centimeters
GDM	Grass Dry Matter
GLM	Generalized Linear Model
HP	Highly Palatable
K	Potassium
Kg Ha^{-1}	Kilograms/hectare
LBM	Lowest Browsable Material
LP	Less Palatable
MNR	Mpofu Nature Reserve
MP	Moderately Palatable
MS/cm	MiliSeimens/centimeter
N	Nitrogen

P	Phosphorus
PP	Poorly Palatable
SANBI	South African National Biodiversity Institute
SAS	Statistical Analysis System
SE	Standard Error
SOM	Soil Organic Matter
WPC	Weighted Palatability Composition

CHAPTER 1. INTRODUCTION

1.1 Background of study

Rangelands support about one-quarter of South Africa's estimated 48.5 million people (Statistics South Africa, 2007) and all of the national livestock herd of cattle, goats and sheep. Rangelands are highly varying in physical, biological, climatic and human activity dimensions. Rangelands are the major source of forage for livestock, and they provide habitat for a great variety of native plants and animals. Overgrazing (which is caused by overstocking) and land degradation are characteristic features of many rangelands (Moyo *et al*., 2008). Rangeland degradation has drastically extended at an alarming rate during the last few decades in Southern Africa because of recurrent and extended droughts, global climate change, overgrazing and poor management practice (Palmer *et al*., 1997) and the interaction of these causes.

The major rangeland use and management systems in South Africa are communal grazing, commercial farming or ranching and game reserves. Management practices, production objectives, animal types, animal number per unit of area, available grazing resources as well as feeding programs are different in these land management systems. Smet and Ward (2005) indicated that communal grazing lands are used by multiple owners who have little regard for grazing land management, while commercial farms and game reserves have only a single manager. The authors stated that communal lands and game reserves are used by diverse animal species whereas commercial farms are often utilised by single species. A continuous grazing on diverse vegetation types and landscapes drives the grazing activities in communal livestock and game reserve, though animals select areas for grazing. In commercial ranches, grazing areas are divided into homogenous units (camps) and are subjected to rotational grazing practice manipulated by human intervention (Smet and Ward, 2005).

For several decades, rangelands have been subjected to external intervention in order to support animal production. Watering points are focal points of grazing by domestic and some native animals in rangelands. Concentrations of relatively large numbers of domestic grazers such as sheep and cattle around watering points, particularly over summer, create gradients of degradation across the landscape, with the magnitude of trampling and its associated degrading effects such as replacement of desirable plant species by less desirable ones (Fusco *et al*. 1995; Todd, 2006). Areas available to grazing increase with distance from the watering point, resulting in a reduction in the relative grazing intensity with distance (Todd, 2006). Nash *et al*. (2003) stated that changes across grazing gradients include changes in species composition, diversity and richness, soil compaction, changes in surface roughness, changes in soil particle mobilization, alterations to the normal flow of surface water, and reduction in vegetation cover of perennial plants. According to Andrew (1988), many of these changes could reach an irreversible situation, and may lead to substantial reductions in ecosystem functions such as soil nutrient cycling and infiltration.

1.1 Problem statement

Visual observation attests that most rangelands in the semi-arid areas of Eastern Cape Province are exposed to rangeland degradation, particularly in areas surrounding focal grazing points such as watering points, homesteads, and kraals. Commercial ranches, game reserves and communal areas use artificial water sources for animal drinking besides the natural sources from streams and rivers. The development of artificial water points may change the vegetation distribution and soil properties within a certain radius from the water points and in severe cases may have degradative effects on the surrounding ecosystem. Nevertheless, in Eastern Cape, studies that have investigated the degradation effect of watering points on the surrounding vegetation and soil are not adequate. Moreover, the few available studies did not consider the different land management systems.

1.2 Justification

Developing a grazing plan for using rangeland resources requires information about the productive capability of the rangelands (Bestelmeyer *et al*., 2003), current condition, intended use, and land owner's objectives. The main use of rangelands in savanna areas is grazing by wild and domestic animals. The improvement of rangeland management is essential for improving livestock and game production in the country. The current study provided understanding on the level and extent of changes in vegetation and soil properties around the water points. These in turn will help design grazing and resource use strategies as well as restoration and conservation interventions of degraded areas around water points. The information generated in this study contributes to a science that conceptualizes the dynamics of rangeland ecosystems, and to rangeland use and practice.

1.4 Objectives

1.4.1 General objective

The general objective is to provide understanding on the level and extent of changes in vegetation and soil properties around water points.

1.4.2 Specific objectives

i. To determine the effects of land management systems and water points on herbaceous species yield, composition, diversity and richness in communal, commercial and game farming;

ii. To determine the effects of land management systems and water points on density and structure of woody plants distribution;

iii. To determine the effects of land management systems and water points on soil physical and chemical properties;

1.3 Null Hypothesis

i. There is no effect of land management systems and water points on herbaceous species yield, composition, diversity and richness in three land management systems.

ii. There is no effect of land management systems and water points on density and structure of woody plants distribution.

iii. There is no effect of land management systems and water points on soil physical and chemical properties.

REFERENCES

Andrew, M.H. 1988. Grazing impact in relation to livestock watering points. *Trends in Ecology and Evolution* **3**: 336–339

Bestelmeyer, B.T., Brown, J.R., Havstad, K.M., Alexander, R. Chavez, G. and Herrick, J.E. 2003. "Development and use of state-and transition models for rangelands." *Journal of Range Management* **56 (2)**: 114–126.

Fusco, M.J., Holechek, J., Tembo, A., Daniel, A. and Cardenas M. 1995. Grazing influence on watering point vegetation in the Chihuahuan Desert. *Journal of Range Management* **48**: 32–38.

Moyo, B., Dube, S., Lesoli, M. and Masika, P.J. 2008. 'Communal area grazing strategies: institutions and traditional practices. *African Journal of Range and Forage Science* **25 (2)**: 47–54

Nash, M.S., Jackson, E., Whitford, W.G. 2003. Soil microtopography on grazing gradients in Chihuahuan Desert grasslands. *Journal of Arid Environments* **55**: 181–192.

Palmer, A.R., Tanser, F. and Hintsa, M.D. 1997. Using satellite imagery to map and inventorise vegetation status for Eastern Cape Province. Unpublished report, Range and Forage Institute, Grahamstown.

Smet, M. and Ward, D. 2005. A comparison of the effects of different rangeland management systems on plant species composition, diversity and vegetation structure using grazing gradients around water points in a semi-arid savanna. *African Journal of Range and Forage Science* **22**: 59–71.

Statistics South Africa. 2007. The People of South Africa. Population Census 1996. National Census. South African Statistical Services.

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

CHAPTER 2. REVIEW OF LITERATURE

2.1 Multiple uses of Rangelands

Ecosystem is a biological community of interacting organisms and their physical environment. Rangelands are vast areas of land on which native vegetation consists predominately of grasses, grass-like plants, forbs, and/or shrubs (Hardin, 1968). Rangelands may consist of grasslands, woodlands, savannahs, shrub lands, most deserts, tundra's, alpine communities, coastal marshes, and wet meadows. Rangelands may include naturally or artificially re-vegetated lands that provide a plant cover that is similar to native vegetation (Tapson, 1993). Rangelands are good sources of forage for free grazing animals as well as a source of woody products, water and wildlife (Ainslie *et al*., 1997). Thus they play an important role in the social, cultural and/or economical activities (Tapson, 1993). Hardin (1968) stated that rangelands are also managed principally with extensive practices such as managed livestock grazing and prescribed fire rather than more intensive agricultural practices of seeding, irrigation, and the use of fertilizers.

2.2 Land management systems in rangeland ecosystems

The three major land management systems in rangeland ecosystems are communal grazing, commercial ranches and game reserves and parks. In the Eastern Cape, it has been reported that the larger portion which is degraded is communal areas (Palmer *et al*., 1997), which could be due to miss-management high stocking rates. In response to a decline in profit margins and negative opinions associated with domestic livestock production, Palmer and Ainslie (2006) documented that there has been a marked shifting of commercial ranches to game farming and ecotourism.

2.2.1 Communal land management system

Communal areas are the oldest land management system dating back to the beginning of livestock rearing in the world. Communal rangelands are the main source of livestock feed for poor resource communal livestock owners. Lesoli (2008) stated that communal rangelands are utilized and managed under a communal land tenure system. The grazing management is poorer in communal lands than commercial due to the poor resources even though it is not always the case. Unfenced camps in communal grazing areas allow free range of livestock, which allow them to have access in rangelands throughout seasons; hence called continuous grazing. Communal people keep livestock for various objectives such as for regular or occasional income, subsistence (milk and meat), traditional ceremonies and savings, meeting social obligations that may entail slaughter or displaying status.

Different livestock species (cattle, goats, chicken, sheep, pigs and horses) are kept for different purposes in communal areas. Communal areas are used by animals and people for different purposes such as grazing, collecting fuel wood, medical plants and harvesting of live wood. The excessive harvesting of wood is reported as one of the factors of changes in vegetative structure, leading to the loss of certain plant species thereby disturbing the soil surface (Shackleton, 1993). Fabricius (1997); Palmer *et al*. (1999) reported that communal rangelands in the Eastern Cape have low biomass and biodiversity. The forage availability is high during the wet season and low during the dry season (Godfrey *et al*., 2003). This shortage of forage during winter/dry season is due to the low rainfall and temperature experienced in winter.

Trollope and Coetzee (1975) stated that one of the major problems that limit livestock production in the communal areas is rangeland degradation. According to the Eastern Cape Department of Agriculture (2004), the Eastern Cape Province is one of the three most degraded provinces in South Africa. Vast communal areas show degradation in a form of erosion ranging from the slightest erosion such as sheet, crust formation to the most severe erosion in a form of rills and gullies.

The first observable form of degradation in all land management systems is loss of vegetative cover, change in species composition and bush encroachment. Meadows and Hoffman (2003) ascertained and quantified that that bush encroachment is severe in the rangelands of the Eastern Cape and communally held lands are likely more affected than commercially farmed areas. Bare ground which is when distance to the nearest plant is greater than 40cm from the marked step point (Tefera *et al*., 2010) is one of the early stages of rangeland degradation; hence it is good indication of over-utilization. A very low basal cover is one the early indicators of rangeland degradation. Baars *et al*. (1997) observed that normally basal cover of excellent vegetation is expected to be greater than 12%. Many studies reported that overgrazing, drought, poor grazing practices and high tree densities are the factors that lead to a low basal cover and high soil loss from the surface hence it initiate the rangeland degradation.

2.2.2 Commercial land management system

Commercial areas consist of land that is privately owned by mainly white farmers who market their products and produce through the formal commercial sector (Hoffman and Todd, 2000). Commercial ranches are the well-developed industries which include private and government-owned ranches. In description of commercially-managed areas, Mbatha and Ward, (2006) reported that they had the highest tree density in the rocky habitat and lower plant quality than other management types. The commercial ranches are mainly used for beef cattle production and as a center for cattle breeding in a resting of camp and rotational grazing system (Tefera *et al*., 2010); hence they can also specialize with any other animal species or production. Nevertheless land degradation occurs on commercial ranches in spite of rotational grazing and under-utilization than on communal ranches. Mbatha and Ward (2006) recommended that commercial ranchers should introduce a greater variety of stock and/or game to reduce selective grazing of certain plant species.

2.2.3 Game reserves and parks

Double-Drift and Mpofu game reserves focus on ecotourism and conservation, trophy hunting and red meat production. Game reserves differ in management structure, animal diversity, management of grazing resources, and products with commercial ranches and communal grazing lands. They include wildlife management, game keeping and wildlife conservation. Most commercial livestock ranches and game reserves in South Africa and other countries are managed by rangeland managers with secondary education and even some degree of tertiary education (Dlamini *et al*., 2000). In terms of management of grazing resources, continuous grazing in diverse vegetation is practiced in game. Smet and Ward (2005) stated that high quantity and diversity of products are produced in communal grazing areas, while high quality of single product for domestic and international markets is produced in commercial ranches. Moreover, in game reserves, high variety and strong healthy big animals for trophies or eco-tourism is produced.

2.3 Rangeland degradation

Rangelands constitute a valuable yet inexpensive resource for poor rural people. Rangeland degradation consists of a reduction in the quantity or nutritional quality of the vegetation available for grazing (Smet and Ward, 2006). Smet and Ward (2006) indicated that prospect of increased rangeland degradation is common to all dry land areas whereas deterioration is more advancing in semi-arid and sub-humid areas than in arid areas. Rangeland degradation is an ecological problem because it reduces rangeland primary productivity and soil protection (Lesoli, 2008). It is commonly described in terms of loss a palatable perennial plant, invasion of undesirable plant species and soil erosion.

2.3.1 Causes of rangeland degradation

Land degradation is a process that causes the reduction in resources potential (soil/land) of natural rangelands. This process is mainly characterized by the loss in vegetation cover, which leads to the occurrence of bare and denuded patches, increased soil erosion, changes in species composition as well as bush encroachment by indigenous and alien invasive plant species in savannah areas. Degradation of rangelands has drastically extended during the last decades due to overstocking, extended periods of drought, global climate change, overgrazing and general mismanagement of the land.

Warren and Khongali (1992) reported that grazing by livestock rather than by game is often the main cause of vegetation and soil degradation. Many researchers, however, felt that rangeland degradation is mainly caused by a combination of changes in land use practices and climate variability (Blirlicc, 2003). It has been reviewed by many researchers that recent decades, increasing human and livestock populations, disruption of traditional management and agricultural conversion of communal pastures have caused widespread rangeland degradation (reviewed by Coppock, 1994; Angassa and Beyene, 2003; Tefera *et al*., 2007).

2.3.2 Indicators of rangeland degradation

The continuing or accelerating sequence of rangelands degradation shows common features, including deterioration in the quantity, quality and persistence of native pastures, generally associated with a reduction of plant cover, but also with invasion by shrubs of low pastoral value; frequently unpalatable and of little economic value or practical use (Everson and Hatch, 1999). Rangeland degradation also include changes in soil surface conditions, notably compaction through trampling by livestock, leading to deterioration in soil, plant-water relationships and reduced germination rate, particularly of the palatable species (Ward *et al*., 2000). Ellis and Swift (1988) viewed that additional processes of sand drift siltation, leading to further destruction of the vegetation and deterioration of surface and shallow groundwater supplies may serve as rangeland degradation indicators.

2.4. Effect of land management systems on vegetation and soil

Land management change can cause a change in land cover and an associated change in carbon stocks as reported by Bolin and Sukumar (2000). Therefore, the change from one ecosystem to another could occur naturally (grassland to mixedveld) due to heavy stocking for example or to be the result of human activity such as for food or timber production.

2.5 Development of animal watering points

Water is crucial in life for both animals (livestock and wildlife) and vegetation. Scarce water availability can limit the survival and growth of livestock and wildlife especially in arid environments. Few scattered natural animal drinking points lead to livestock not getting sufficient water, and that results in those few areas (watering points) being over utilized. Location of animal drinking points has been reported to influence the distribution of livestock and wildlife, and as a consequence, a radial gradient of plant cover and dung density (Bailey *et al*., 1996). Hence, the provision of water in arid and semi-arid rangeland has been documented that it changes the spatial distribution of livestock. Development of animal watering points can cause the development of wetlands that support native plants and animals, also increase abundance of native animals which need to drink regularly (Craig *et al*., 1999).

2.5.1. Effect of animal watering point on plants community structure

Gradients of animal impact known as piospheres have been widely reported to develop around artificial watering points, particularly in arid and semi-arid areas (Todd, 2006). Such grazing gradients represent a potential opportunity for differentiating the long-term effects of livestock activity from other environmental patterns (Todd, 2006). Mohamed *et al*. (2010)

discussed the impact of watering point provision on the plant cover, species richness and community structure of Tunisian arid rangelands, from the context of the evolutionary history as well as current grazing management practices. Todd (2006) reported in Namibian shrublands that highly disturbed areas immediately adjacent to watering points are dominated by forbs and a large proportion of alien species. Landsberg *et al*. (2003) reported in Australian rangelands that areas adjacent to water point's zone are dominated by widespread shrub species of medium to low palatability whereas areas most distant from watering points contained a greater proportion of species known to be highly palatable to livestock.

2.5.2. Effect of animal watering point on soil properties

Soil physical and chemical characteristics can be altered by the animal grazing distribution. Such soil characteristics subject to change are organic matter, soil pH, soil solution electric conductivity and soil nutrients (e.g. N, P, and K). Soil characteristics support grassland ecosystems physically, chemically and biologically. Impacts of grazing on soil fall into two broad categories: firstly the physical impact of the animal on soil as it moves around and secondly the chemical and biological impact of the faeces and urine that the animal deposits on the soil. Physically damaged soil can be even more susceptible to the chemical and biological impact of faeces and urine. Cattle, buffalo, elephant and others compact soil structure and destroy vegetation in the area they trample most often. This is visually apparent around drinking water troughs, entrances to fields and other parts of the field and other parts of the land where the animals congregate.

Livestock grazing intensity gradient associated with artificial watering points has effects on physical environment including changes of soil nutrient levels (Tolsma *et al*., 1987; Perkins and Thomas, 1993; Todd, 2006), soil compaction (Andrew and Lange, 1986a), infiltration and development of footpaths around water points (Thrash, 1997). Smet and Ward (2006) reported that change in soil properties and nutrients generally occurred within 100 m radius from animal watering points. Tolsma *et al*. (1987) reported that changes in soil nutrients in Eastern Botswana rangelands occur up to distance of 100 m from the water point, while Turner (1998) and Dougill *et al*. (1999) found changes within a distance of 200 m from watering points.

2.6 Rangeland condition assessment

Rangeland condition is the current state of plant composition and animals of a particular community in comparison to some perceived potential (Caudle, 1993). Costello (1956) reported that rangeland condition needs to be determined to indicate necessary management inputs. Livestock, wildlife, watershed and recreation are management goals that are need to be determined (Schacht, 1993). Rangeland condition assessment determines if range is ecologically intact, soil is stable, carbon and nitrogen cycles functioning properly and the water cycle is intact (e.g., infiltration, water table, run off). The rangeland assessment approach stresses soil health and stability, and vegetative reproduction (Caudle, 1993).

There are several debates on which components of a range ecosystem to focus on when assessing rangelands. For example, some argue only soil and grass components, while others suggest a three tier system including soil, woody vegetation, and grass vegetation. Lesoli (2008) reported that grass tuft diameter and distance between tufts is an indication of basal cover between degraded and non-degraded areas, however, step-point method (Mentis, 1981) used to estimates the proportional species composition. The name of the nearest plant, basal strikes and bare patches from each plot are recorded, and the results are expressed as the percentage of each species encountered in the survey (Hardy and Walker, 1991). All rooted live plants are counted in each plot for the estimation of plant density per unit area and converted into hectare with the exception of non-woody plants.

A pocket penetrometer (Model 16-T0171, 1999) can be used to measure unconfined compressive strength (UCS) of the soil which occurs when moist or wet soil aggregates are pressed together and the pore space between them is reduced. Compaction changes soil structure, reduces the size and continuity of pores, and increases soil density (bulk density). Also, loss of topsoil changes the capacity of the soil to function and restricts its ability to sustain future uses. Erosion removes topsoil, the layer of soil with the greatest amount of organic matter, biological activity, and nutrients, creating a less favorable environment for plant growth. Erosion breaks down soil structure, exposing organic matter within soil aggregates to decomposition and loss.

Disc pasture meter is used to measure the standing grass biomass (Trollope, 1979a), which is one of the components of a range ecosystem to focus on when assessing rangelands. Rangeland parameters that are not highly susceptible to yearly climatic variation need to be selected when assessing rangeland condition, for example, measuring basal cover is better than canopy cover or biomass and measuring frequency would be better than density or cover (Schacht, 1993).

2.6.1. Range condition assessment methods and techniques

Rangeland condition assessment is an essential management tool for qualifying and quantifying change in range vegetation and soil properties condition in order to monitor effective management and indication of the necessary management inputs. Solomon *et al*. (2007) stated that rangeland assessment measures range deterioration and improvement changes in vegetation productivity of rangelands on short term or long term basis.

Rangeland condition assessment can be assessed by employing two common methods which are weighted palatability composition (WPC) and Ecological Index Method (EIM) even though there are several others. WPC was proposed by Barnes *et al*. (1984), whereby the livestock production potential of a site is based purely on immediate forage palatability potential. However, three classes were described for the purpose of classifying grassland species, that is, class 1, highly palatable, class 2, intermediate and class 3-unpalatable. EIM 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. For the calculation of the rangeland condition index based on ecological merits, the grass species are categorized into four classes (decreaser, increaser (I, II and III) group and invader species under EIM technique (Vorster, 1982). Each class was given a relative index value, namely: decreaser = 10; increaser IIa = 7; increaser IIb = 4 and increaser IIc = 1 (Vorster, 1982).

REFERENCES

Ainslie, A., Cinderby, S., Petse, T., Ntshona, Z., Bradley, P.N., Deshingkar, P., Fakir, S. 1997. Rural livelihoods and local level natural resource management in Peddie district. Stockholm Environment Institute Technical Report.

Andrew, M.H. and Lange, R.T. 1986a. Development of a new piosphere in arid chenopod shrubland grazed by sheep. I. Changes to the soil surface. *Australian Journal of Ecology* **11**: 395–409.

Angassa, A. and Beyene, F. 2003. Current range condition in southern Ethiopia in relation to traditional management strategies: the perceptions of Borana pastoralists. *Tropical Grassland* **37**: 53–59

Baars, R.M.T., Chilishe, E.C. and Kalokoni. 1997. Technical notes: range condition in high cattle density areas in the Western Province of Zambia. *Tropical Grasslands* **31**: 569 573.

Bailey, D.W., Gross, J.E., Laca, E.A., Rittenhouse, L.R., Coughenour, M.B., Swift, D.M. and Sims, P.L. 1996. Mechanisms that result in large herbivore grazing distribution patterns. *African Journal of Range Management* **49**: 386–400.

Barnes, D. L., Rethman, N. F. G., Beukes, B. H. and Kotze, G. D. 1984. Veld composition in relation to grazing capacity. *Journal of the Grassland Society of South Africa* **1**: 16-19.

Bolin, B. and Sukumar, R. 2000. Global perspective. In: Land Use, Land-Use Change, and

Forestry (eds WatsonRT, NobleIR, BolinB, RavindranathNH, VerardoDJ, DokkenDJ), pp. 23–51. Cambridge University Press, Cambridge, UK.

Blirlicc, A.S. 2003. Eco Restore - a decision support system for the restoration of degraded rangelands in Southern Africa. MSc Thesis, Potchefstroom University.

Caudle, D. 1993. Traditional range condition concepts defended. *Rangelands* **15**: 244–246.

Coppock, D.L. 1994. The Borana plateau of southern Ethiopia: synthesis of pastoral research, development and change, 1980–91. Addis Ababa: International Livestock Centre for Africa.

Costello, D.F. 1956. Factors to consider in the evaluation of vegetation condition. *Journal of Rangeland Management* **9**: 73–74.

Craig, J., Landsberg, J. and Morton, S.R. 1999. Provision of watering points in the Australian arid zone: a review of effects on biota. *Journal of Arid Environments* **41**: 87–121.

Dlamini, B. J., Khumalo, G. Z. and Xaba, B. B. 2000. Cattle performance and nutritive value of pastures on Swazi Nation Land. *Journal of Agricultural Science and Technology* **3 (2)**: 38–44.

Dougill, A.J., Thomas, A.D. and Heathwaite, A.L. 1999. Environmental change in the Kalahari: integrated land degradation studies for non-equilibrium dryland environments. *Annals of American Geographers* **89**: 420–442.

Eastern Cape Department of Agriculture. 2004. State of environment in South Africa:

indicators of land degradation. (online) available from: http://www.environment.gov.za/soer/ecape/indicators/land/land_degradation.htm.

Ellis, J.E. and Swift, D.M. 1988. Stability of African pastoral ecosystems: alternate paradigms and implications for development. *Journal of Range Management* **41**: 420–459.

Everson, T.M. and Hatch, G.P. 1999. Managing veld (rangeland) in the communal areas of Southern Africa. In: Tainton, N.M. (Ed.), Veld management in South Africa. University of Natal Press, Pietermaritzburg. pp. 381–388.

Fabricus, C.A. 1997. The impact of land use on biodiversity in Xeric Succulent Thicket, South Africa. *Bulletin of the Southern African Institute of Ecologists and Environmental Scientists* **16 (2)**: 15–17.

Godfrey, R.W., Weis, A.J. and Dodson, R.E. 2003. Effect of Flushing Hair Sheep Ewes During the Dry and Wet Seasons in the U.S. Virgin Islands. *Journal of Animal and Veterinary Advances* **01/2003**.

Hardin, G. 1968. The tragedy of the commons. *Science* **162**:1243–1248.

Hardy, M.B. and Walker, L.S. 1991. Determining sample size for assessing species composition in grassland. *Journal of the Grassland Society of Southern Africa* **8**: 70–73.

Hoffman, M.T. and Todd, S. 2000. A national review of land degradation in South Africa: the influence of biophysical and socio-economic factors. *Journal of Southern African Studies* **26**: 743–758.

Landsberg, J., James, C.D., Morton, S.R., Müller, W.J. and Stol, J. 2003. Abundance and composition of plant species along grazing gradients in Australian rangelands. *Journal of Applied Ecology* **40**: 1008–1024.

Lesoli, M. S. 2008. Vegetation and soil status, and human perceptions on the condition of communal rangelands of the Eastern Cape, South Africa. MSc Thesis, University of Fort Hare.

Mbatha, K.R. and Ward, D. 2006. Determining spatial and temporal variability in quantity and quality of vegetation for estimating the predictable sustainable stocking rate in the semi-arid savanna, African Journal of Range and Forage Science **23 (2)**: 131–145.

Meadows, M.E. and Hoffman, T.M. 2003. Land degradation and climate change in South Africa. *The Geographical Journal* **169(2)**: 168–177.

Mentis, M.T. 1981. Evaluation of the wheel-point and step-point methods of veld condition assessment. *Proceedings of the Grassland Society of southern Africa* **16**: 89–94.

Model 16-T0171. 1999. Pocket penetrometer. Instructional manual.

Mohamed, T., Farah, B.S., Azaziez, O.B. and Mohamed, N. 2010. Acceptability of plant species along grazing gradients around watering points in Tunisian arid zone.

Palmer, A.R., Tanser, F. and Hintsa, M.D. 1997. Using satellite imagery to map and inventorise vegetation status for Eastern Cape Province. Unpublished report, Range and Forage Institute, Grahamstown.

Palmer, A.R., Ainslie, A.M. and Hoffman, M.T. 1999. Sustainability of commercial and communal rangeland systems in southern Africa. pp. 1020–1022, in: *Proceedings of the 6th International Rangeland Congress*. 17-23 July 1999, Townsville, Australia.

Palmer, T. and Ainslie, A. 2006. Country Pasture/Forage Resource Profiles.

Perkins, J.S. and Thomas, D.S.G. 1993. Spreading deserts or spatially confined environmental impacts: land degradation and cattle ranching in the Kalahari Desert of Botswana. *Land Degradation and Rehabilitation* **4**: 179–194.

Schacht, W.H. 1993. A new approach for range condition assessment is needed. Rangeland **15**: 245–247.

Shackleton, C. 1993. Are communal rangelands in need of saving? Development Southern Africa. **10**: 65–67.

Smet, M. and Ward, D. 2005. A comparison of the effects of different rangeland management systems on plant species composition, diversity and vegetation structure using grazing gradients around water-points in a semi-arid savanna. *African Journal of Range and Forage Science* **22**: 59–71.

Smet, M. and Ward, D. 2006. Soil quality gradients around water-points under different management systems in a semi-arid savanna, South Africa. *Journal of Arid Environment* **64**: 251–269.

Solomon, T., Snyman, H.A. and Smit, G.N. 2007. Rangeland dynamics in Southern Ethiopia: Botanical composition of grasses and soil characteristics in relation to land use and distance from water in semi-arid Borana Rangelands. *Journal of Environment Management,* in press **85 (2):** 429–442.

Tapson, D. 1993. Biological sustainability in pastoral systems: the KwaZulu Natal case. In: Behnke, Jr., R.H., Scoones, I., Kerven, C. (Eds.), Range Ecology at Disequilibrium: New Models of Natural Variability and Pastoral Adaptation in African Svannas. Overseas Development Institute, London, pp. 118–135.

Tefera S., Snyman, H.A. and Smit, G.N. 2007. Rangeland dynamics in southern Ethiopia: (1) Botanical composition of grasses and soil characteristics in relation to land-use and distance from water in semi-arid Borana rangelands. Journal of Environment Management **85**: 429–442.

Tefera, S.B., Dlamini, B.J. and Dlamini, A.M. 2010. Soil nutrients and grass species structure in relation to land management systems and soil classes in the semi-arid Lowveld rangelands. *Journal of Arid Environments* **74**: 675–684.

Thrash, I. 1997. Infiltration rate of soil around drinking troughs in the Kruger National Park South Africa. *Journal of Arid Environments* **35**: 617–625

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

Tolsma, D.J., Ernst, W.H.O. and Verwey, R.A. 1987. Nutrients in soil and vegetation around two Artificial water points in Eastern Botswana. *Journal of Applied Ecology* **24**: 9991-1000.

Trollope, S.W. and Coetzee, P.G.F. 1975. Vegetation and veld management. In:Laker M.C.

(ed) The Agricultural Potential of the Ciskei: A preliminary report, pp. 71–124. Faculty of Agriculture, University of Fort Hare, Alice.

Trollope, W.S.W. 1979. Ecological effects on fire in South African savannas. *Proceedings Symposium Dynamic Changes in Savanna Ecosystems*, in 1979.

Turner, M.D. 1998. Long-term effects of daily grazing orbits on nutrient availability in Sahelian West Africa: 1. Gradients in the chemical composition of rangeland soils and vegetation. *Journal of Biogeography* **25**: 669–682.

Vorster, M. 1982. The development of the ecological index method for assessing veld condition in the karoo. *Proceedings of the Grassland Society of Sothern Africa* **17**: 84–89.

Ward, D., Ngairorue, B.T., Karamata, J., Kapofi, I., Samuels, R., Ofran Y. 2000. Effects of Communal pastoralism on vegetation and soil in a semi-arid and in a n arid region of Namibia. *Proceedings IAVS Symposium* 1998:344–347.

Warren, S.D., Thurow, T.L., Blackburn, W.H. and Garza, N.E. 1986. *African Journal of Range Management* **39**: 491–495.

Warren, A. and Khogali, M. 1992. Assessment of Desertification and Drought in the Sudano-Sahelian Region, 1985–1991. United Nations Sudano-Sahelian Office, New York, 115 pp.

CHAPTER 3: Yield and species composition response to different land management systems and distance from water sources.

ABSTRACT

The objective of this study was to investigate the effects of land use and distance from water point on grass biomass yield, species distribution and composition. Six study sites, two from communal (Upper Gqumashe and Kwezana grazing areas), commercial (Honeydale and Glen-Muir ranches) and game reserves (Double Drift and Mpofu game reserve) were selected. Two watering points were selected from each land management system. Two 500 m transects were laid along selected watering points and divided in to sub-transects at 25 m, 50m, 100m, 200m, 300m and 500m from water points. A 100 m^2 plot was marked in each sub-transect to record grass biomass and species composition. Data were collected for two seasons of year 2012/13 (winter and summer). Thirty grass species were identified in all study areas. The most common species were *Cynodon dactylon, Digitaria eriantha, Eragrostis obtusa, Setaria sphacelata* and *Sporobolus fimbriatus*. All the grass species had similar ($p > 0.05$) abundance along distance from water points. Grass dry matter (GDM) showed significant difference ($p < 0.05$) between land uses; between ranches, game reserves or communal areas within each land use. However, GDM was not significantly ($p > 0.05$) affected by season, location of water point within each farm or reserve and distance along water points. Grass species composition and GDM did not significantly respond to distance gradient from water points and this may explain that either grazing gradient was absent or the short length of transects as limited by the presence of fences was not enough to explain the absence or presence of gradients. Differences between land use systems or sites within each land use may be explained either by spatial variations in climate, soil and topography, animal species and management practices.

Keywords: herbaceous

3.1. Introduction

Three main animal production and management systems can be recognized in the extensive rangeland ecosystems of South Africa: communal, commercial ranch and game reserves. These production systems differ in terms of available grazing resources, resource management and use as well as production objectives. Communal rangelands are owned and managed by the communal people of certain area with every member having access to resources without temporal and/or spatial restriction. According to Smet and Ward (2005), communal grazing lands are used by people who have little regards for grazing land management, and keep mixed livestock species (cattle, goats, sheep) to meet their social, cultural and economical needs together. The main purposes of raising livestock on free rangelands are therefore to generate regular or occasional income, produce milk and meat production for consumption, traditional ceremonies and savings, manure, traction and meeting social obligations that may entail slaughter or displaying status.

Commercial ranches are mainly private ranches (with the exception of few states owned ranches which have commercial set up but are used mainly for research and breeding purposes). They are used mainly by single or two livestock species, and raised for commercial sales of live animals and/or their products. Most commercial ranches practice systematic rotational grazing by dividing the grazing land into homogenous units (camps). Commercial ranching in South Africa is a well-developed industry owned mainly by resourceful and educated farmers who market their products and produce through the formal commercial sector (Hoffman and Todd, 2000). Game reserves include national parks, nature reserves and game ranching. Unlike the commercial livestock farms, game reserves do not practice strict rotational systems, but keep diverse species of game animals. Production and management objectives of game reserves vary depending on the type of the reserve. For instance, game ranching, a fast-growing sector in South Africa, with growth rate record of

6.75% per annum since 1993 (Kieser, 2001; Tomlinson *et al*., 2002), focuses mainly on ecotourism, trophy hunting and venison production (Smet and Ward, 2005). On the other hand, national parks and nature reserves focus primarily on conservation and protection of the diversity of wild animals, associated fauna, their habitats and distinctive landscapes, while eco-tourism and trophy hunting are secondary. All the three land management systems have also some commonalities in that they rely mainly on natural resources within a certain climatic and edaphic boundaries, and use both natural and man-made (artificial) sources of water for animal drinking. In particular, in most African countries, the use of artificial water points has been growing compared to the use of natural water sources in all the land management systems (Pople and Page, 2002).

Several studies have examined vegetation and soil disturbance gradients around water points. Lange (1969) first used the term piosphere to refer to the radial disturbance gradients formed around a point of focal grazing because of long-term herbivore impact. However, such studies and conclusions drawn have been subject to debates over several decades because other effects related to land management systems, and environmental factors were not examined together. Todd (2006) stated that areas available for grazing increase with distance from the watering point, resulting in less grazing intensity and disturbance away from watering points. In contrast, Bonifica (1992) in Botswana rangelands and Van Rooyen *et al*. (1990) in the South Africa Kalahari Gemsbok National park observed the absence of any significant variations in vegetation composition around water points. Smet and Ward (2005) concluded that that less variance in vegetation is explained by difference in grazing pressure along transect from the water point than is explained by differences among land management systems.

Some recent findings (e.g. Smet and Ward, 2005; Solomon *et al*., 2007; Tefera *et al*., 2010) attempted to determine the most important causes of ecosystem changes across spatiotemporally heterogeneous semi-arid African rangelands. However, such studies had often experimental limitations to draw up rational conclusions. For instance, Smet and Ward (2005) and Tefera *et al*. (2010) hinted respectively that the spatio-temporal heterogeneity of precipitation and edaphic factors often make comparisons between land management systems difficult to investigate their influence on the rangeland ecosystems. Within a management system, acquiring homogenous replicate farms is also another problem because farms, even though they have similar objectives of raising animals, may have different farm grazing capacities, grazing and management systems as well as edaphic, vegetation and geographic units. At farm level, spatial and temporal heterogeneity of soil and vegetation often make selection of homogeneous sampling unit difficult. Despite the challenges, these studies produced some evidences on the level and extent of vegetation and soil changes and the causes of these changes at micro, medium and macro level land scales. Indeed, such information could help formulate grazing and resource use strategies as well as restoration and conservation interventions of degraded areas. The studies have also contributed to scientific debates that conceptualize the dynamics of rangeland ecosystems.

The Eastern Cape Province is the second-largest province of South Africa after the Northern Cape, taking up 13.9% of the country's land area and has a population of around 6.5-million people (Census, 2011). Rolling grasslands dominate the eastern interior of the province, while the western central plateau is savanna bushveld and the northern inland is home to the aromatic, succulent-rich Karoo habitat. Though the majority of the land is communal, many commercial and game reserves are present in the province. Indeed, domestic stock farming is slowly giving way to game farming on large scale, fueled by the commercial benefits of eco-tourism and the lower risk needed to protect wild game against drought, the natural elements and pouching (Census, 2011). Nevertheless, relatively few studies have examined the yield and species composition characteristics of the herbaceous layer in relation to land management systems and grazing disturbances around water points.

The objectives of this study was therefore 1) to investigate the effect of land management systems and water points on the herbaceous species yield, species distribution and composition, and 2) to determine relationships between environmental and species variables.

3.2. Materials and methods

3.2.1. Description of the study area

This study was conducted in the savannas of the Eastern Cape province of South Africa. The mean maximum and minimum temperature in summer varies between 15^{o}C and 26.3^{o}C and in winter 8^{o}C to 18.4^{o}C of the selected sites (World Atlas, 2012). The three main vegetation types in the study areas are Bisho Thronveld which is under the Savanna biome; Great Fish Thicket and Eastern Cape Escarpment both of which fall under the Albany Thicket biome (Mucina and Rutherford, 2011). Bisho Thornveld is characterized by the dominance of perennial grasses and small acacia trees. The major geology and soil types in the Bisho Thornveld are mudstones with subordinate sandstones of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup) underlying most of the area. The soil texture shows significant variability, but is generally dominated by loamy soil. Annual rainfall in the Thornveld ranges from 500 mm in the west to more than 900 mm in the east (Mucina and Rutherford, 2011). Albany thicket is characterized by the abundance of succulent and non-succulent trees, shrubs and perennial grasses. The distribution pattern of some plant species vary between veld types. The major geology and soil types in Albany Thicket are mudstones and arenite of the Adelaide subgroups of the Karoo super-group as well as Jurassic dolerite intrusions. The soils are mostly shallow with dominant textures of fine-grained, nutrient-poor silts or more nutrient-rich clay soils. Annual rainfall ranges from 300 mm in the western inland areas to 600 mm in the eastern coastal areas (Mucina and Rutherford, 2011).

3.2.2. Site selection

Two communal grazing areas, two commercial ranches and two game reserves were selected for this study. The two communal areas are named as Upper Gqumashe and Kwezana. Upper Gqumashe grazing land is about 559 ha and is used by cattle and goats at stocking rates of about 6 ha/head and 4.4ha/head, respectively. Kwezana grazing land is estimated to be 730 ha and has stocking rates of 2.0 ha/head for cattle and 2.6 ha/head for goats. The communal areas are approximately 10 km from each other. The two commercial cattle ranches are Honeydale ranch and Glen Muir commercial cattle ranch and are found approximately 24km from each other. Honeydale ranch belongs to the University of Fort Hare and has an area of about 635ha stocking rates of 2ha/head for cattle and 3.5 ha/head for indigenous veld goats, Glen Muir is a privately owned ranch and has an area of 1550ha and stocking rate of 11ha/head. The two game reserves are Double Drift and Mpofu Game reserve and are located approximately 38km from each other. Double Drift game reserve has about 29 animal species whereas; Mpofu game reserve has 21 species. Kudu, Eland, Warthog, Baboon and Buffalo are found as dominating species in Double Drift, while in Mpofu game reserve Eland, Plain Zebras, Black Wildebeest, Blesbok and Red Hartebeest found dominating. Double Drift has an area of about 23500 ha and stocking rate of 4.2 ha/head, whereas, Mpofu game reserve has an area of about 8500 ha and stocking rate of 4.5 ha/head. The two communal areas, Honeydale ranch and part of Glen Muir ranch fall under the Bisho Thornveld savanna, while the game reserves and part of the Glen Muir ranch fall under Albany thicket vegetation (Figure3.1).

3.2.3. Selection of watering points and transect layout

Two watering points were selected from each grazing area with an average distance of 500 m - 2.5km between the two water points within a farm or game reserve. At each water point, two 500m straight transects were laid on either sides of the watering points. Each transect was sub-divided into sub-transects at 25 m, 50 m (considered as near sites) 100 m, 200 m (middle sites) 300 m and 500 m (far sites) from the water point. The length of transects could not go beyond 500 m due to the presence of fence lines. At each distance a 100 m^2 plot was marked to record herbaceous species composition, basal cover, and biomass production. Vegetation sampling was conducted in winter (May-July, 2012) and summer (November-January, 2012/13) seasons. Coordinates and altitudes of the study areas are presented in Table 3.1.

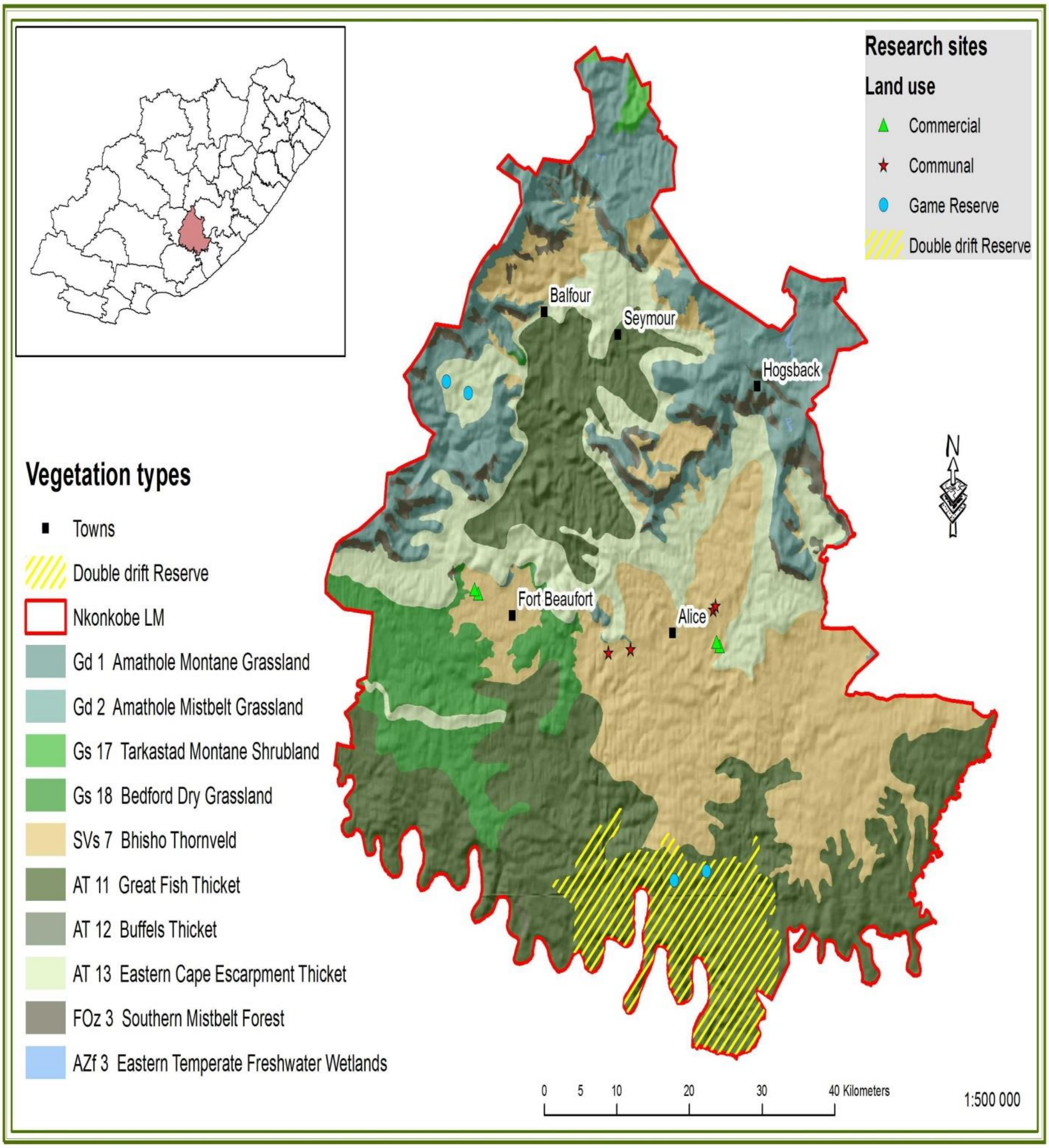


Figure 3.1. Study site and water points in each land management system.

Table 3.1. Coordinates and altitudes of the study sites

Land management systems	Water Point	Coordinates	Altitude
<u>Communal:</u>			
Upper Gqumashe	1	S32^{o}46,227’ E26^{o}52,927	656
	2	S32^{o}46,046’ E26^{o}53,124	640
Kwezana	1	S32^{o}48,107’ E26^{o}46,786	616
	2	S32^{o}48.259’ E26^{o}45.139	561
<u>Game reserve</u>:			
Double Drift	1	S32^{o}58.614’ E26^{o}52.431	415
	2	S32^{o}59.050’ E26^{o}50.030	415
Mpofu	1	S32^{o}36.004’E26^{o}34.718	816
	2	S32^{o}35.451’E26^{o}33.077	916
<u>Ranch:</u>			
Glen-Muir	1	S32^{o}58.588’E26^{o}52.526	371
	2	S32^{o}45.279’E26^{o}35.196	479
Honeydale	1	S32^{o}47.760’ E26^{o}53.196	570
	2	S32^{o}47.964’ E26^{o}53.424	541

3.2.4. Data collection

Herbaceous species composition and basal cover was measured using 1 m long Levy Bridge frame. The frame has 10 steel rods with sharp point at the tip and 10 cm apart. The frame was lowered to the ground randomly as quadrant and the nearest plant to each rode and the basal strikes on the base of the plants were recorded. The procedure was repeated three times within each 100m^2 plots to give a total of 30 points per plot (Levy and Madden, 1933). Basal strikes were recorded as basal cover. The relative abundance of each plant species was calculated as the percentages of the sum of the nearest plant and basal strike divided by the total points which is 30. For grass biomass determination, grass samples were harvested separately from three 0.25 m^2 quadrates per 100 m^2 and placed in paper bags. The samples were taken and oven dried for 48 hours at 60^oC and then weighed using a digital weighing scale.

3.2.5 Species classification

Classification of grasses was based on the succession theory described by Dyksterhuis (1949) and on the ecological information for the arid to semi-arid regions of South Africa (Foran, 1976; Tainton *et al.*, 1980; Vorster, 1982). Species were grouped based on their ecological and response to grazing as: (i) highly desirable species: those which occur in rangeland in good condition and decrease with overgrazing (decreaser species); (ii) desirable species: those which occur in rangeland in good condition and increase with moderate over grazing (increaser IIa), and (iii) less desirable species: those which occur in rangeland in good condition and increase with severe/extreme overgrazing (increasers IIb and IIc). Also species were grouped according to their life forms as annuals, weak perennials and strong perennials (van Oudtshoon, 1999).

3.2.6. Statistical analysis

Herbaceous data were analyzed using a General Linear Model (GLM) of SAS (2001) to test differences between land management systems, between sites (farms or reserves) within land management systems and between water points within site, and between distances within watering points. The canonical correspondence analysis (CCA) of CANOCO version 4.5 software (ter Braak and Šmilauer, 2002) was used as a multivariate analysis tool to further investigate the relationship between the plant species and environmental variables which are; altitude (describes land management and site within land management), season, and distance along water point. For data that do not require analysis, simple descriptive statistics were employed where appropriate.

3.3. Results

Thirty grass species were identified in all study areas. Of these, 23 species were strong perennials, three species were annuals and four species were weak perennials. Ten species of the identified grasses were highly palatable, nine were moderately palatable, two were less palatable species and nine species were poorly palatable (Table 3.2).

3.3.1. Abundance of common or dominant grass species

3.3.1.1. Effect of land management systems

Common or dominant grass species in this context are defined as those species recorded in several study plots under each land-management system and had >5-12% (common) or >12% (dominant) average occurrence at least in one of the land management systems. Accordingly, of 30 grass species identified, 10 were classified as common or dominant species. These were *Digitaria eriantha*, *Themeda triandra*, *Cynodon dactylon*, *Sporobolus fimbriatus*, *Eragrostis obtusa*, *Eragrostis capensis*, *Eregrostis chloromelas*, *Setaria sphacelata*, *Sporobolus africanus* and *Cymbopogon pospischilii*. *Digitaria eriantha* and *T. triandra* were more ($p < 0.05$) abundant in the communal grazing areas and commercial ranches than the game reserves, whereas *C. dactylon* and *S. sphacelata* were more frequent in the game reserves than the other land management's (Table 3.3). The occurrences of *S. fimbriatus* and *E. obtusa* were significantly ($p < 0.05$) lower in the communal area compared to the ranch and the game reserve, but *E. capensis*, *E. chloromelas* and *S. africanus* were more abundant ($p < 0.05$) in the communal lands than in the game reserves and commercial ranches. *Cymbopogon pospischilii* was significantly ($p < 0.05$) less abundant in communal and game reserve areas than the ranch (Table 3.3).

Table 3.2. Life form, ecological status and palatability of grasses in the study areas.

Species	Life Forms	Palatability	Ecological Value	Ranch	Communal	Game reserve
Aristida congesta	A	PP	Inc II c	R	+	R
Aristida junciformis	P	PP	Inc III	+	+	+
Brachiaria serrata	P	MP	Dec	+	+	+
Cynodon dactylon	WP	HP	Inc II c	R	C	D
Cymbopogon pospischilii	P	PP	Inc I a	C	+	R
Digitaria eriantha	P	HP	Dec	D	D	C
Elionurus muticus	P	PP	Inc II c	+	+	+
Eragrostis capensis	P	MP	Inc II a	R	C	R
Eragrostis chloromelas	P	MP	Inc II b	R	C	R
Eragrastis curvula	P	MP	Inc II b	+	+	+
Eragrostis lehmanniana	P	MP	Inc II c	+	+	+
Eragrostis obtusa	WP	MP	Inc II c	C	R	C
Eragrostis plana	P	PP	Inc II c	C	+	+
Eustachys paspaloides	P	HP	Dec	+	+	+
Heteropogon contortus	P	MP	Dec	+	R	R
Hyparrhenia hirta	P	MP	Inc I a	+	+	+
Karrochloa curva	A	PP	Inc II c	+	+	+
Melica decumbens	P	PP	Inc I b	+	+	C
Microchloa caffra	P	PP	Inc II c	R	R	R
Paspalum dilatatum	WP	HP	Invader	+	+	+
Panicum aequinerve	P	HP	Dec	+	R	R
Panicum maximum	P	HP	Dec	+	+	+
Panicum stapfianum	P	HP	Dec	R	+	+
Setaria sphacelata	P	HP	Dec	+	+	D
Sporobolus africanus	P	PP	Inc II b	R	C	R
Sporobolus fimbriatus	P	HP	Dec	C	R	R
Sporobolus nitens	WP	LP	Inc II c	R	+	R
Themeda triandra	P	HP	Dec	C	C	R
Tragus berteronianus	A	LP	Inc II c	R	+	+
Tristachya leucothrix	P	MP	IncI c	+	R	+

Note: + = present (<1%); R = rare (>1 – 5%); C = common (>5 – 12%); D= dominant (>12%). PP–Poor Palatable; LP-Less Palatable; MP-Moderate Palatable; HP-Highly Palatable. Inc (Increaser species); Dec (Decreaser species). A – Annuals; P – strong perennials; WP – Weak perennials. Source: (Tefera, 2013)

Table 3.3. Grass species composition (%) and total dry matter yield (Kg ha^{-1}) in relation to land management systems.

Grass Species	**Land management**			**SEM**	**Significance**
	Com	**Game**	**Ranch**		
Digitaria eriantha	23.1^{a}	10.4^{b}	26.6^{a}	2.25	<0.0001
Themeda triandra	11.7^{a}	4.2^{b}	11.2^{a}	1.54	<0.0008
Cynodon dactylon	8.33^{b}	13.2^{a}	4.8^{b}	1.62	<0.0014
Sporobolus fimbriatus	2.0^{b}	4.6^{a}	6.5^{a}	0.84	<0.0008
Eragrostis obtusa	2.0^{b}	8.7^{a}	8.9^{a}	1.37	<0.0003
Eragrostis capensis	10.8^{a}	1.5^{b}	4.7^{b}	1.22	<0.0001
Eragrostis chloromelas	9.6^{a}	2.3^{b}	4.1^{b}	1.05	<0.0001
Setaria sphacelata	0.8^{b}	13.8^{a}	0.7^{b}	1.28	<0.0001
Sporobolus africanus	5.7^{a}	3.2^{b}	3.3^{b}	0.77	<0.0322
Cymbopogon pospischilii	0.5^{b}	1.1^{b}	7.5^{a}	0.81	<0.0001
Total Dry Matter	1496.5^{b}	1913.7^{a}	2033.9^{a}	84.9	<0.0001

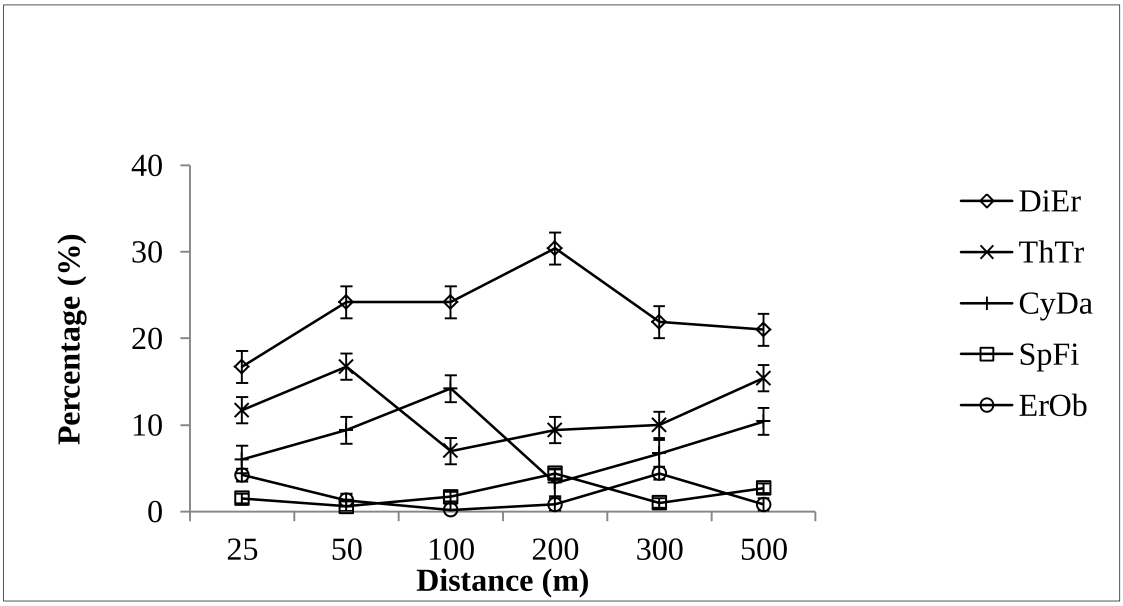
^{a,b,c} Means in the same row with different superscripts are significantly different ($p < 0.05$). SEM = standard error of means; Com – communal.

3.3.1.2. Effect of season, site, water point location and distance

Except for *E. capensis* ($p < 0.001$), *S. africanus* ($p < 0.01$) and *C. pospischilii* ($p < 0.0001$) which showed higher occurrence in summer than winter, the abundance of the other species did not respond to seasonal changes. However, all species except *S. fimbriatus* showed great variability of abundance between sites (i.e. between farms or reserves) within each land management system. The abundance of *D. eriantha* ($p < 0.01$), *C. dactylon* ($p < 0.0001$), *E. chloromelas* ($p < 0.01$) and *C. pospischilii* ($p < 0.0001$) were significantly different between water-points within each farm or game reserve (Table 3.4). The abundances of all grass species didn't show any significant response ($p > 0.05$) to distance gradient from water points (Figure 3.2a, 3.2b and 3.2c).

Table 3.4. F-value and p-value of grass species composition and total dry matter yield between season, sites and water-points within sites.

Species	Between season		Between sites		Between water-points within sites	
	F	P	F	P	F	P
Digitaria eriantha	1.4	0.2318	3.3	0.0229	9.7	0.0022
Themeda triandra	0.3	0.6105	31.8	0.0001	0.3	0.6036
Cynodon dactylon	0.3	0.5629	7.3	0.0001	20.2	0.0001
Sporobolus fimbriatus	0.4	0.5299	1.3	0.2718	0	0.9873
Eragrostis obtusa	0.9	0.3517	22.2	0.0001	3.0	0.0870
Eragrostis capensis	13.0	0.0004	16.9	0.0001	0.1	0.7817
Eragrostis chloromelas	0.1	0.8193	22.0	0.0001	8.1	0.0051
Setaria sphacelata	1.2	0.2785	51.4	0.0001	0	0.8334
Sporobolus africanus	7.8	0.0059	9.4	0.0001	0.2	0.6801
Cymbopogon pospischilii	89.5	0.0001	6.0	0.0007	23.7	0.0001
Total dry matter yield	10.7	0.0012	8.0	0.0052	1.3	0.2652



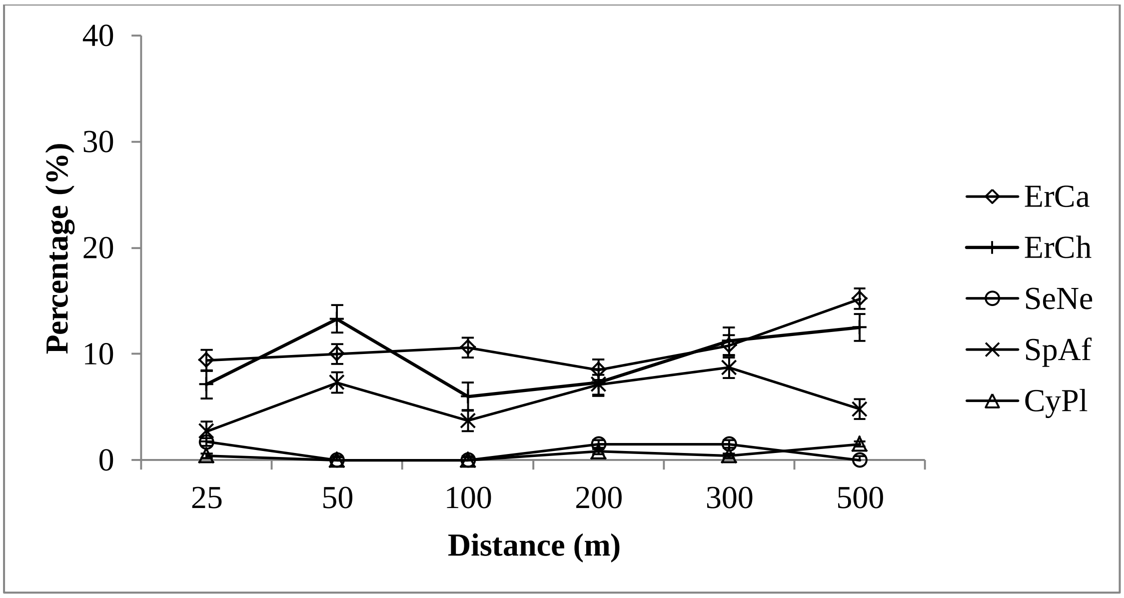
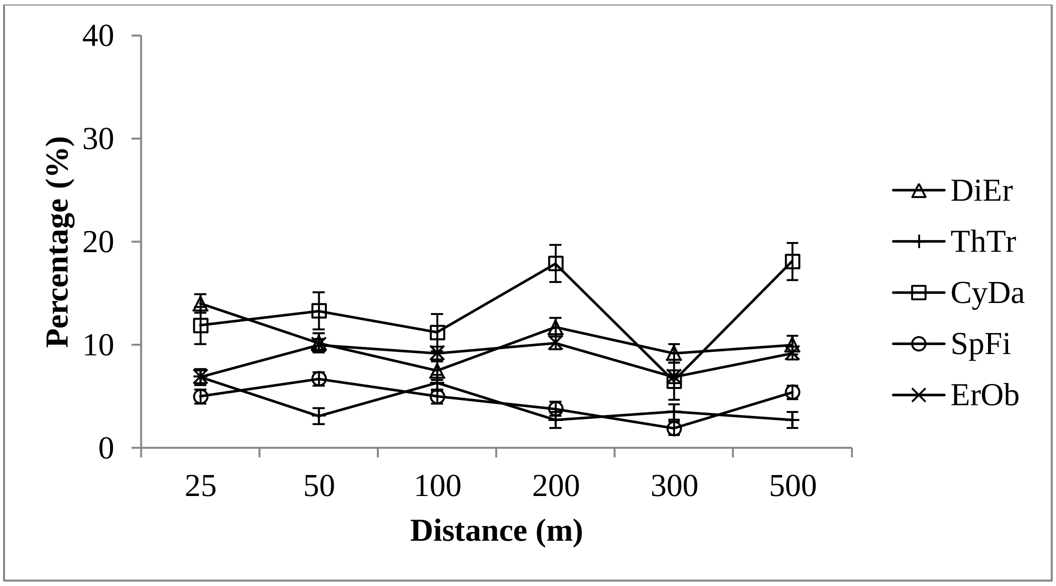


Figure 3.2a. The occurrence of common or dominating grass species along distance from water point in communal land: (*DiEr-Digitaria eriantha, ThTr-Themeda triandra, CyDa-Cynodon dactylon, SpFi-Sporobolus fimbriatus, ErOb-Eragrostis obtusa, ErCa-Eragrostis capensis, ErCh-Eragrostis chloromelus, SeNe-Setaria neglecta, SpAf-Sporobolus africanus, CyPl-Cymbopogon plurinodis*)

3.3.2. Total dry matter (DM) yield

When all sampling points are pooled, the total DM yield of grasses was significantly ($p < 0.0001$) lower in the communal area than the ranch and the game reserves (Table 3.3). Also, DM yield showed greater variability ($p < 0.01$) between the commercial ranches, communal grazing systems, or the game reserves. Pooled data showed that season greatly ($p < 0.01$) affected DM production, with winter having higher yield than summer. However, DM yield showed no significant variations ($p > 0.05$) between water points within sites (Table 3.4). In the communal area, DM yield didn't change considerably ($p > 0.05$) with distance away from water points (Figure 3.3). Nevertheless, in the ranch and game reserves, there was significant ($p < 0.05$) difference in DM yield with distance from water points, but values did not show any increasing or decreasing trend with distance. In the ranch, the highest DM was recorded at 200m from water point (Figure 3.3), while in the game reserves this was recorded close to the watering point (25 and 50 m) (Figure 3.3).



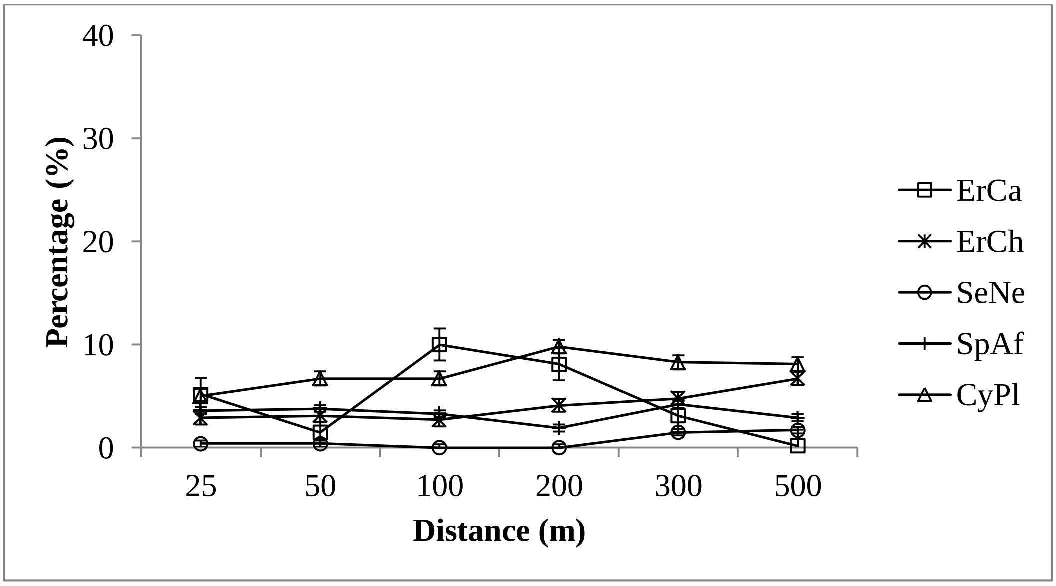


Figure 3.2b. The occurrence of common or dominating grass species along distance from water point in game reserves.

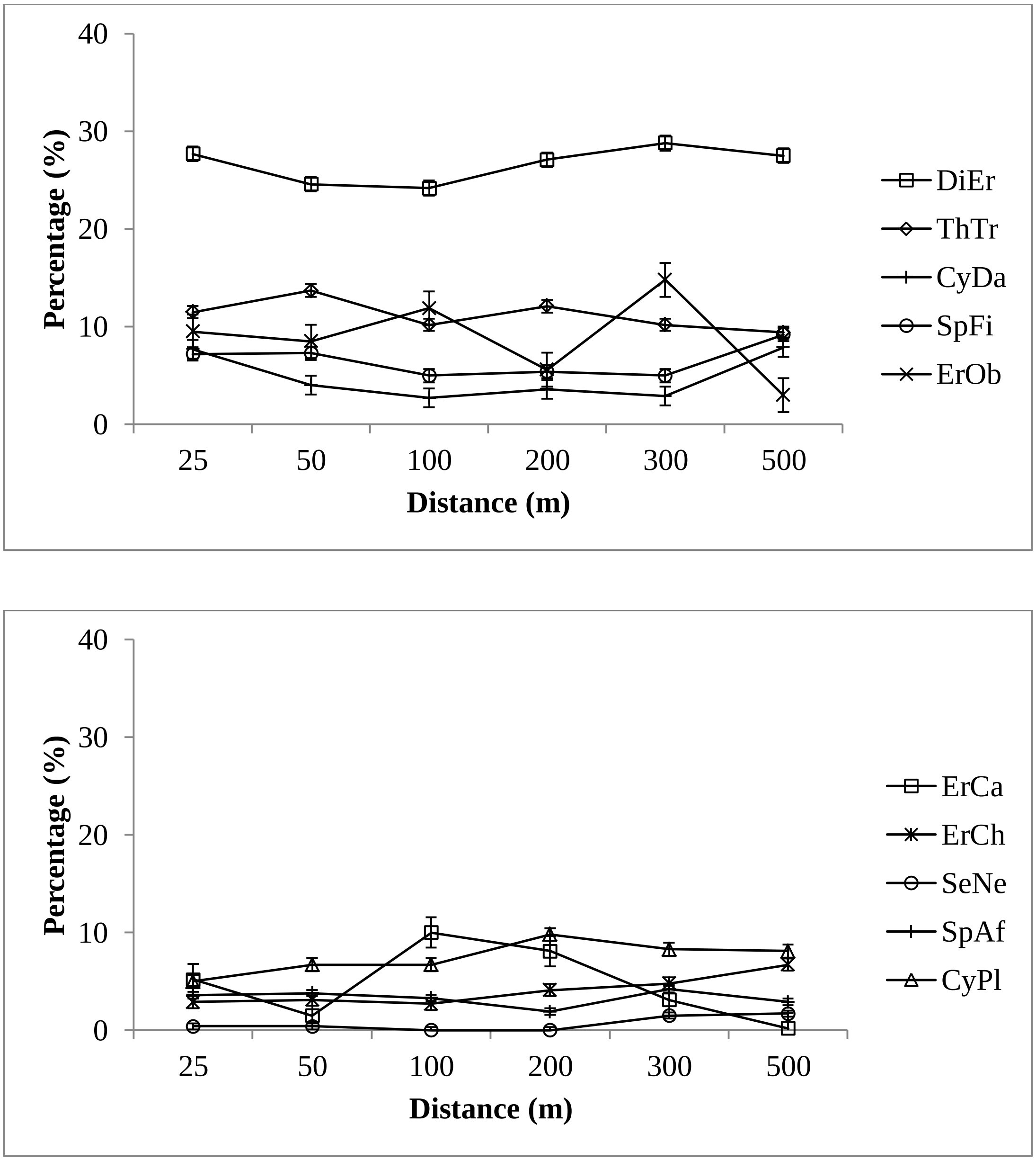


Figure 3.2c. The occurrence of common or dominating grass species along distance from water point in commercial ranch.

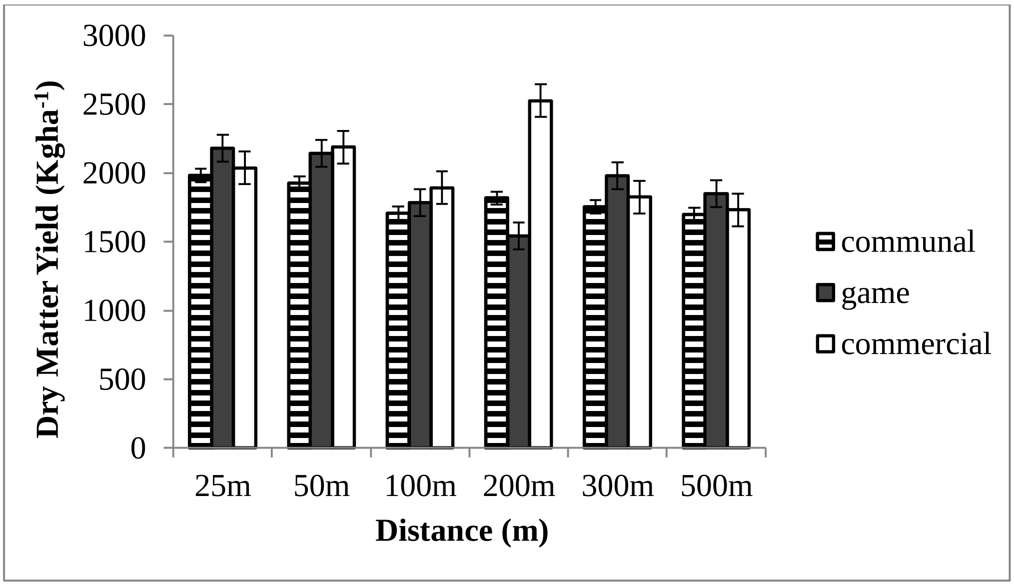


Figure 3.3. Dry matter yield (Kg ha^{-1}) along distance from water point in communal land, game reserves and commercial ranches.

3.3.3 Relationship of environmental variables between dry matter yields along water points

In Figures 3.4–3.9, arrows are extended from the origin to represent the environmental variables in the direction of increasing fitted values (ter Braak and Šmilauer, 2002). By projecting the environmental variables on the line and ranking the projection points, a ranking was obtained of the values of a particular species. In the present study, total grass species frequency, the proportion of perennials, annuals, palatability groups and grass dry matter were added to the species data. In communal area, five environmental variables were related to the species data. Two environmental variables, viz. land management and distance from water points were omitted by automatic forward selection. The key environmental variables that were selected by the automatic forward selection to explain at least 50% of the species variance around water point's areas were site, season and water point location (Figure 3.4-3.9). Ordination results on the relationship between environmental and species variables in the communal sites are presented in Figure 3.4. The results showed that in the communal areas *C. dactylon, E. chloromelas, E. obtusa, A. congesta* and *Karroid* species were positively associated to site, whereas forb, sedge, and *E. plana* were correlated negatively with site. The abundance of sedge and DM yield responded positively. Water location had a weak positive correlation with *S. africanus*, a weak negative correlation with *M. caffra*.

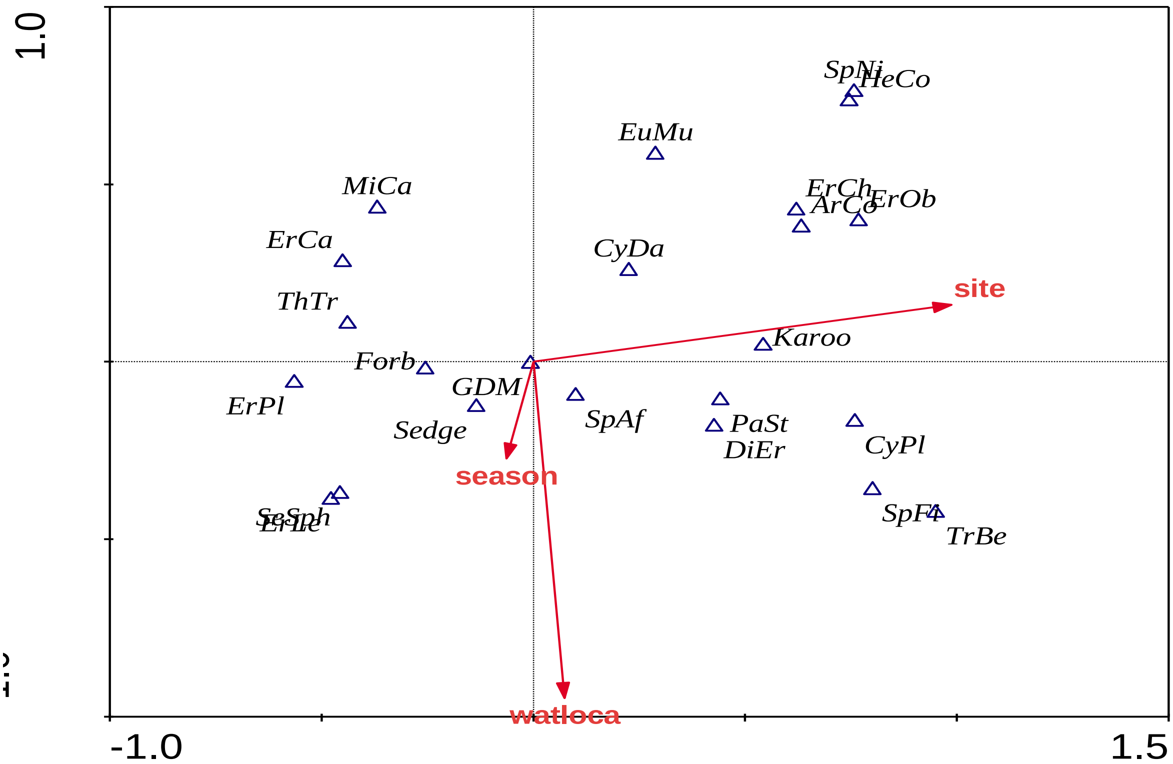


Figure 3.4. Canonical correspondence analysis ordination diagram of the relationship between species (represented by triangles) and environmental (site, season and water points) variables (arrows) in Kwezana and Upper Gqumashe communal areas. Watloca = water points, *ErCa = Eragrostis capensis, ThTr = Themeda triandra, MiCa = Microchloa caffra, EuMu = Eustachys mutica, CyDa = Cynodon dactylon, ErCh* **=** *Eragrostis chloromelas, SpNi = Sporobolus nitens, HeCo = Heteropogon contortus, ArCo = Aristida congesta, ErOb = Eragrostis obtusa, ErPl = Eragrostis plana, SeSph = Setaria sphacelata, ErLe = Eragrostis lehmanniana,* GDM = Grass Dry Matter, *SpAf = Sporobolus africanus, PaSt = Panicum stapfianum, DiEr =Digitaria eriantha, CyPl = Cymbopogon plurinodes, SpFi = Sporobolus fimbriatus, TrBe = Tragus berteronianus.*

Figure 3.5 shows the relationship between environmental variables and palatability or life form groups. The ordination diagram shows that highly palatable grass species were related to the location of water point. Poor palatable species responded positively to both season and site, while highly palatable groups are positively related to water points.

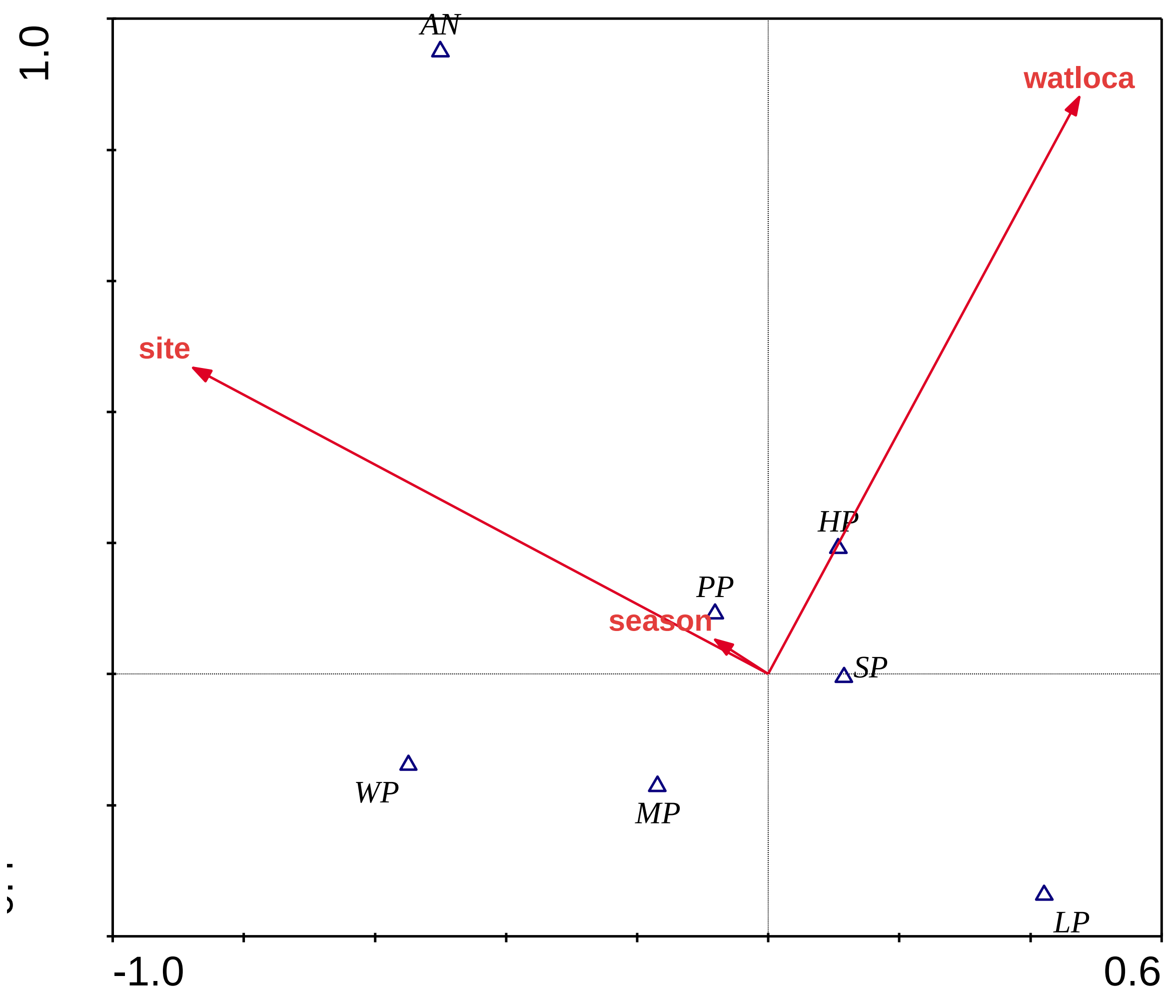


Figure 3.5. Canonical correspondence analysis ordination diagram of the relationship between palatability and life forms (represented by triangles) and environmental (site, season and water points) variables (arrows) in Kwezana and Upper Gqumashe communal areas. Watloca = water points, HP = Highly palatable, MP = Moderately palatable, LP = Less palatable, PP = Poor palatable, SP = Strong perennial, WP = Weak perennial, AN =Annual.

Ordination results on the relationship between environmental and species variables in the game reserves are presented in Fig. 3.6. The results showed that *E. chloromelas* and *E. capensis*, *E. curvula*, forb, *karoo species* and *C. pospischilii* were associated to site differences; whereas the occurrences of sedge and *T. triandra* had strong correlation with water points. *Heteropogon contortus, A. congesta* and *E. obtusa* showed some degree of relationship with season.

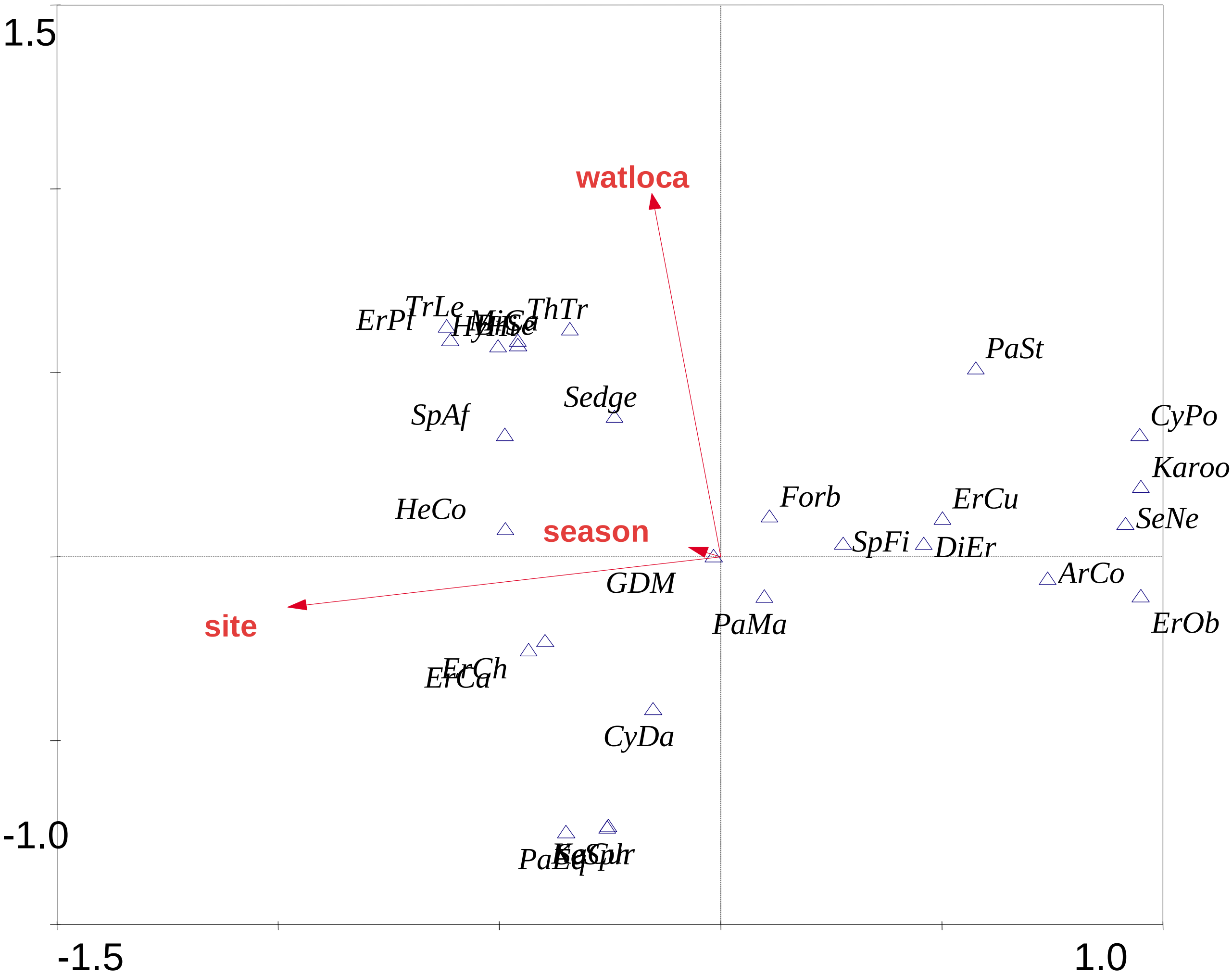


Figure 3.6. Canonical correspondence analysis ordination diagram of the relationship between species (represented by triangles) and environmental (site, season and water points) variables (arrows) in Double Drift and Mpofu game reserves. *ErCu* = *Eragrostis curvula*, *PaMa* = *Panicum maximum*, *PaEq* = *Panicum equiva*, *TrLe* = *Tristachya leucothrix*.

Figure 3.6 presents relationship between palatability groups, life forms and environmental variables. Accordingly poor palatable grass species and strong perennials were strongly associated to water location. Moderately palatable species and annuals have strong relationship with season and sites differences.

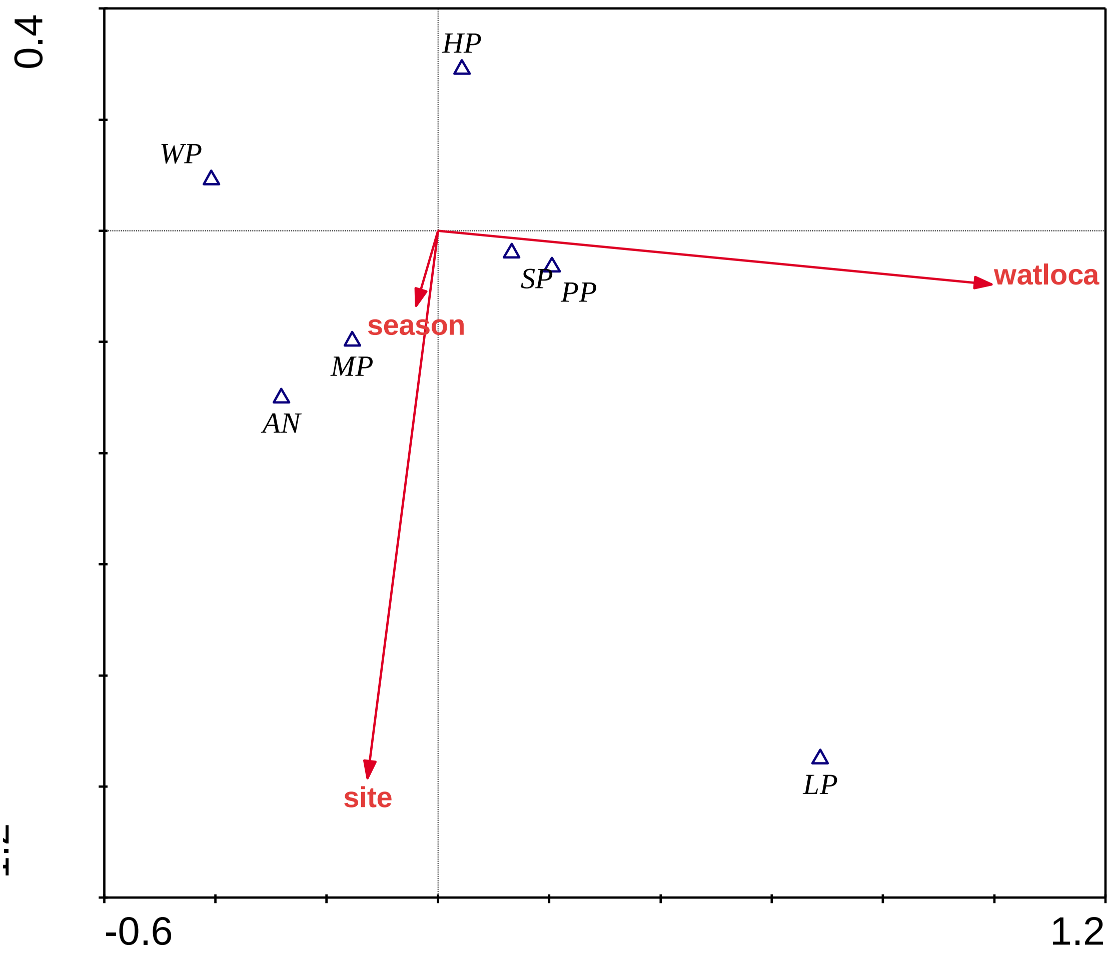


Figure 3.7. Canonical correspondence analysis ordination diagram of the relationship between palatability and life forms (represented by triangles) and environmental (site, season and water location) variables (arrows) in Double Drift and Mpofu game reserves.

Figure 3.8 shows the relationship between environmental and species variables in the commercial ranches. The ordination results show that *C. plurinodes* and the proportion of sedges varied with the location of water points. *Sporobulus fimbriatus*, *P*. *stapfianum* and *T. triandra*, *P. maximum*, *E. obtusa*, *S. nitens* and *karoo* species had strong associations to site. The occurrences of *D. eriantha* and forb species was related to season.

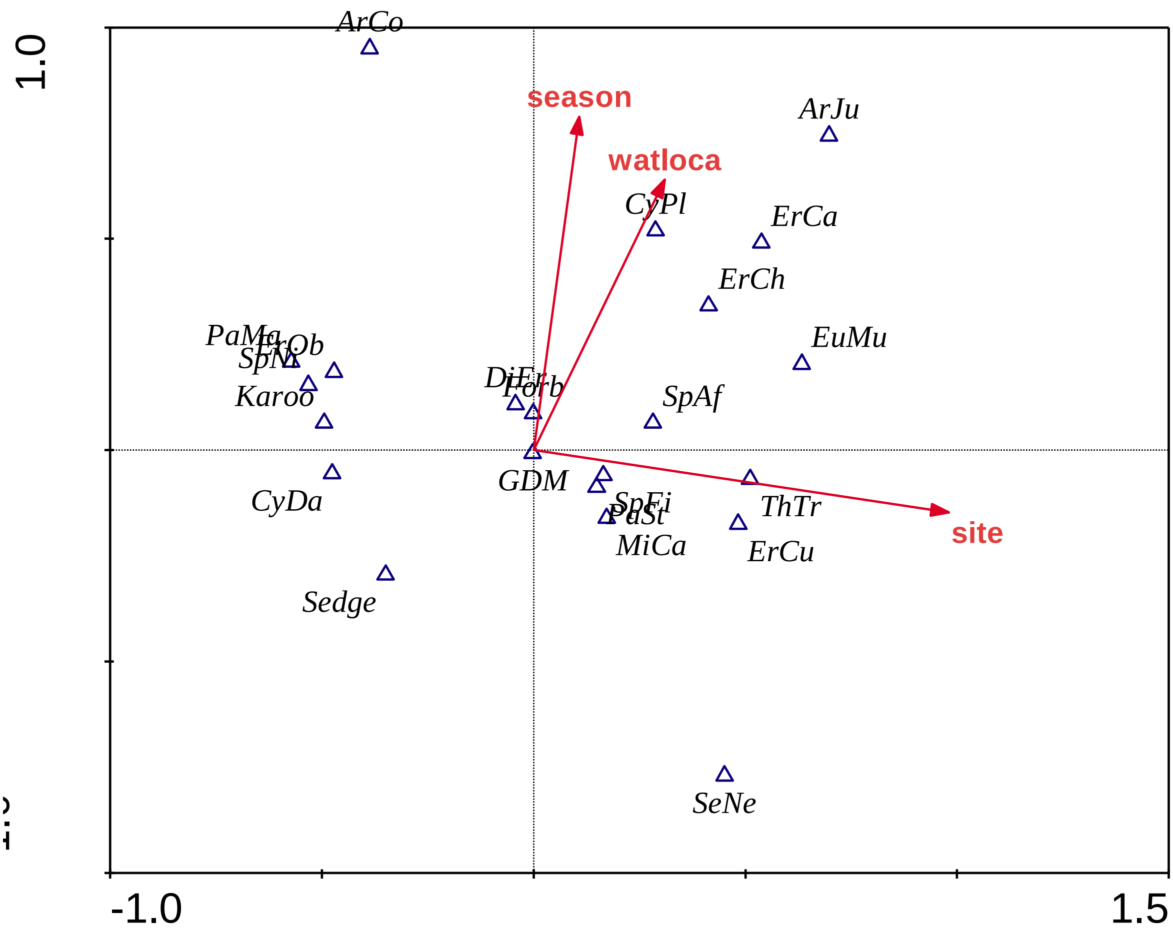


Figure 3.8. Canonical correspondence analysis ordination diagram of the relationship between species (represented by triangles) and environmental (site, season and water points) variables (arrows) in Glen Muir and Honeydale commercial ranches.

The relationship between life forms, palatability groups and selected environmental variables is shown in Figure 3.9. The ordination diagram shows that strong perennial, weak perennials and less palatable grass species were strongly associated to site. Poor palatable species were positively related to season and water points.

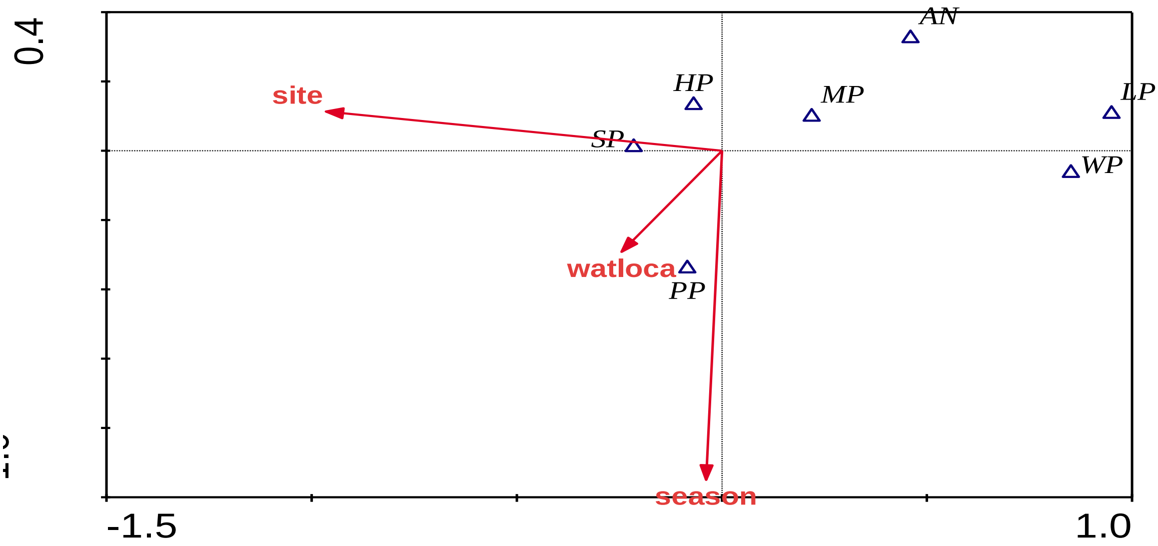


Figure 3.9. Canonical correspondence analysis ordination diagram of the relationship between palatability and life forms (represented by triangles) and environmental (site, season and water points) variables (arrows) in Glen Muir and Honeydale commercial ranches.

3.4. Discussion

3.4.1. Effect of land management systems

Grass species identified in this study were partially similar to previous studies (e.g. *D. eriantha*, *C. dactylon*, *S. sphacelata* and *T. triandra*) in the same ecology (Lesoli, 2008; Magawana, 2011; Kioko *et al*. 2012), though there were some differences in the report of their relative abundance. In this study, although all grass species were recorded in all land management systems, their distribution varies greatly. *Digitaria eriantha* was the only grass recorded as the dominant species in the ranches and communal grazing lands, while in game reserves *D. eriantha* occurred less frequently. The study of de Bruyn and Raats (1999) in the Central Eastern Cape rangelands also showed *D. eriantha* as the most common species in Dyamala communal lands. Though its distribution over large landscape level hints its adaptation to wider habitats, the abundance of this species may be influenced by abiotic factors such soil and topography. In the current study, both the communal and ranch areas share similar abiotic environments, which are greatly different from the game reserve areas. *Digitaria eriantha* is one of the best forage species in Southern Africa and it serves as key indicator of the range condition (Victor *et al.*, 2005). *Digitaria eriantha* is a grass which tolerates heavy grazing once established, and is persistent, drought-tolerant and adapted to wide range of soils (Moore *et al*., 2006).

The relative higher abundance of *C. dactylon* in the game reserves compared to the other land uses may be related to both biotic and abiotic influences. Similarly, Fatunbi and Dube (2008) reported the dominance of *C. dactylon* in Tsolwane Game reserve located in the Eastern Cape. The biotic influence may be related to the history of land management. Game reserves chosen for this study were previously used as cattle ranches at high stocking rate which were then converted to reserves. The population of the game animals at water points at any time and their selective grazing habit for the more palatable species could also be responsible for relative higher abundance of *C. dactylon* in the game reserves compared to other land management types. Solomon *et al*. (2007) and Ayanna and Baars (2000) reported that *C. dactylon* is a good palatable forage that is often fed to calves in the Borana rangelands of South Ethiopia. In Southern Africa, *C. dactylon* is regarded as an average grass (increaser II) which serves as an indicator of severely overgrazed and poor rangelands (Trollope, 1990; Jordaan, 1997; Hardy *et al*., 1999; Van der Westhuizen *et al*., 2005; Fatunbi and Dube, 2008; van Oudtshoorn, 2012).

Setaria sphacelata was recorded as dominant species in the game reserve, but shows very low frequencies of occurrence in the ranches and communal areas. This species is most widely adapted to soil textures ranging from heavy to light clay soils, and in well-drained and sandy soil as well as on stony slopes or sometimes next to streams (Oudtshoorn, 2012).

Setaria sphacelata occurred more frequently inside bush clumps than in open rangelands. All these habitats are more common in the game reserves than the other land management systems. This species is a palatable grass, with an average to high leaf production which is reasonably well utilized by game and stock (van Oudtshoorn, 2012).

The common occurrence of *T. triandra* in Thronveld savannas has been similarly reported by previous studies. *Themeda triandra* is an indicator of rangelands being in good condition and it quickly disappears by overgrazing (O'Connor and Roux, 1995; SANBI, 2011). Most of the common or dominant grass species showed great variability between farms or game reserves within a land management system. Attributing factors to these differences may be limited to topographic and management practices including stocking rate or animal types. Kwezana and Upper Gqumashe communal grazing lands differed mainly in terms of stocking rate, while in Honeydale and Glen-Muir commercial ranches the difference encompasses both stocking rate and altitudes. In the game reserves, the main difference between the reserves is altitude. Environmental and landscape heterogeneity as well as grazing intensity differences were similarly reported by Reitalu *et al*. (2012) to cause vegetation changes in semi-natural grasslands of Sweden. But this view is partially against with Wesulsa *et al*. (2013) who reported that stocking rates had much less influence on species and trait composition in semi-arid African rangelands.

When species are grouped based on their forage value, the occurrences of highly palatable (HP) species were significantly higher in the ranch (46.1%), where the poorly palatable (PP) and less palatable (LP) species were lowest. Beyene (2013) concluded that such scenarios may highlight the presence of less herbivore pressure over the past and present grazing utilization. Significant interaction also existed between land management systems and sites (farms or grazing reserves) on the occurrences of HP, LP and PP groups. As for HP group, the two game reserves, though they have similar stocking rate, showed significantly different percentages, with a game reserve located at higher altitude having lower occurrence of HP. The effect of altitude on the occurrence of HP grass species may be related to variations in micro temperatures and rainfall regimes between the two reserves.

Forage yield or biomass refers to above ground herbaceous material and it is expressed as dry matter weight per unit area of land (Abule *et al.*, 2007). The significantly lower DM yield in the communal areas than the ranches may evidently suggest the presence of both short and long-term high herbivore utilization. However, the lower DM yields in the communal area than the game reserves may be associated primarily to the abiotic factors including soil and altitudes, and secondarily to herbivore utilization. Game reserves are found at higher rainfall regime than communal land which support more dry matter yield.

3.4.2. Effect of season, site water point location and distance gradient on species composition

Digitaria eriantha, *C. dactylon*, *E. chloromelas* and *C. pospischilii* are the only species that showed significantly different frequencies between water points within site (farm or reserve). When species were collectively grouped into their palatability, HP and LP did not significantly differ between water point locations within a farm or reserve, but MP and PP groups did. This may suggest that the four individual species and the two palatability groups (MP and PP) were good indicators of local variations in herbivore effects and therefore may be used as key variables indicators to monitor spatial vegetation change at the farm level. The absence of significant differences in DM yield between water location sites within a farm or reserve suggested that this variable was not sensitive indicator to local differences in herbivore effects.

In this study, the frequencies of all grass species, palatability groups and DM yield did not respond to distance gradient from water points. The length of transects particularly in ranches could not go beyond 500 m due to the presence of fence lines and this may have a blurring effect on the piosphere pattern. Similarly, several studies conducted in semi-arid or arid environments reported the absence of variations in species abundance along a gradient from a focal point (Bonifica, 1992; Tefera, 2013). In contrast, many studies indicated that herbaceous species respond to the piosphere effect around water points (van Rooyen *et al*., 1990; Perkins and Thomas, 1993; Beeskow *et al*., 1995; Nsinamwa *et al*., 2005; Smet and Ward, 2006; Todd, 2006). Child and Riche (1971), Graetz and Ludwig (1978), Perkins and Thomas (1993) also noted that watering points have lead to the development of a gradient of utilization pressure which is greatest near the watering point and decreases as a function of distance from it.

Seasonal changes affected the frequencies of some grass species and the total forage DM yields. The greater abundance of *E. capensis*, *S. africanus* and *C. pospischilii* in summer than winter may be related to the grazing selectivity behaviour of the animals. *Eragrostis capensis* is an average grazing grass, while *S. africanus* and *C. pospischilii* are poor grazing grasses which all may not be preferred forage plants during summer when forage supply is adequate and animals have opportunities to selection. However, these forages may greatly contribute to grazing during winter equally or more than the good forages that are less abundant as the result of summer grazing. The higher total DM yield in winter than summer may be related to either the intra-annual influence of abiotic conditions (e.g rainfall and temperature) on the annual growth cycle of plants to the variations in the temporal distribution of herbivores around the water points or the combination of both. Grazing pressure around water points may be higher in summer than winter season due to high water requirement by animals in summer than winter. However, concentration of grazing pressure around these watering points in summer turn in causing changes in the basal cover, biomass and composition of the plant community.

3.7 Conclusion

The poor rangeland degradation in the current study was mainly caused or due to short-term use of water points by animals of the selected areas. Highly palatable species showed a higher abundance than the less palatable species in all three land management, and this may result in high forage production for livestock around water points. Vegetation variables showed no significant differences along a distance gradient from a water points. Looking at each land management system, different soil type and altitude may determine the vegetation structure and change and hence the livestock population and diversity. Hence, at the medium scale (between water points within sites) land forms, livestock densities and different stocking rate numbers within sites may play the overriding role in changes of the herbaceous layer. At the micro level surrounding of water points, soil type and livestock populations around water points didn't show any significant variation or response on vegetation and DM yield. Therefore, distance along watering points may be used as indicator of disturbance gradient in all land management systems. Moreover, total DM may increase or decrease along watering points hence, it may be used as indicator of disturbance gradient between land management systems.

REFERENCES

Abule, E. Snyman, H.A. and Smit, G.N. 2007. Rangeland evaluation in the Middle Awash Valley of Ethiopia: I. Herbaceous vegetation cover. *Journal of Arid Environments* **70**: 253–271.

Ayanna, A. and Baars, R.M.T. 2000. Ecological condition of encroached and non encroached rangelands in Borana, Ethiopia. East African Wild life Society. *African Journal of Ecology* **38**: 321–328.

Beeskow, A.M., Elissalde, N.O. and Rostagno, C.M. 1995. Ecosystem changes associated with grazing intensity on the Punta Ninfas rangelands of Patagonia, Argentina. *Journal of Range Management* **48**: 517–522.

Beyene, S.T. 2013. Rangeland degradation in a semi-arid communal savannah of Swaziland: long–term dip-tank use effects on woody plant structure, cover and their indigenous use in three soil types. Land Degradation and Development. *African Journal of range and forage sciences*.

Bonifica, (1992). Technical Assistance to the Department of Wildlife and National parks: Initial measures for the conservation of Kalahari ecosystem. Project N.6100.026.14.001.

Census 2011: Census in brief. Pretoria: Statistics South Africa. 2012. ISBN 9780621413885.

Child, G., Parris, R. and Riche, E. 1971. Use of mineralized water by Kalahari wildlife and its effects on habitats. *East African Wildlife Journal* **9**: 125–142.

de Bruyn, T.D. and Raats, J.G. 1999. The productivity and sustainability of communal rangelands in central Eastern Cape. Short paper, Grasslands of Society of Southern Africa, 34th Annual Congress, Warmbaths.

Dyksterhuis, E.J. 1949. Condition and management of rangeland based on quantitative ecology. *Journal of Range Management* **2**: 104–115.

Fatunbi, A.O. and Dube, S. 2008. Land degradation evaluation in a game reserve in Eastern Cape of South Africa: soil properties and vegetation cover. *Scientific Research and Essay* **3(3)**: 111–119.

Foran, B.D. 1976. The development and testing of methods for assessing the condition of three grassveld types in Natal. M.Sc Thesis, University of Natal, Pietermaritzburg, South Africa.

Graetz, R.D. and Ludwig, J.A. 1978. A method for the analysis of piosphere data applicable to range assessment. *Australian Rangeland Journal* **1**: 117-125.

Hardy, M.B, Hurt, C.R. and Bosch, O.J.H. 1999. Veld condition assessment. N.M. Tainton (Ed.), Veld Management in South Africa, University of Natal Press, Scottsville, South Africa, (1999) pp. 472.

Hoffman, T. and Todd, S. 2000. National review of land degradation in South Africa: The influence of biophysical and socio-economic factors. *Journal of Southern African studies* **26**: 743–758.

Jordaan, F.P. 1997. Implementation of a computerized system for assessing rangeland condition and monitoring in a number of key grazing areas of the western grassland Biome. Ph.D Thesis, Potchefstroom University for CHE, Potchefstroom, South Africa.

Keiser, I. 2001. Special seksie: jag en tourisme. Landbouweekbland, 16 March 2001: 43-53.

Kioko, J., Kiringe, J.W. and Seno, S.O. 2012. Impacts of livestock grazing on a savanna grassland in Kenya. *Journal of Arid Land* **4(1)**: 29–35.

Lange, R.T. 1969. The piosphere: sheep track and dung patterns. *Journal of Range Management* **22**: 396–400.

Lesoli, M. S. 2008. Vegetation and soil status, and human perceptions on the condition of communal rangelands of the Eastern Cape, South Africa. MSc Thesis, University of Fort Hare.

Levy, E. B. and Madden, E. A. 1933. The point method of pasture analysis. *New Zealand Journal of Agriculture* **46**: 267–279.

Magawana, M. 2011. Investigating long -term effects of burning frequency on nutritional contents of selected grass species in a South African semi-arid savanna. MSc Thesis. University of Fort Hare.

Moore, G., Sanford, P. and Wiley, T. 2006. Perennial pastures for Western Australia, Department of Agriculture and Food Western Australia, Bulletin 4690, Perth.

Mucina, L. and Rutherford, M.C. (eds). Reprint 2011. The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South Africa National Biodiversity Institute, Pretoria.

Nsinamwa, M., Moleele, N.M. and Sebego, R.J. 2005. Vegetation patterns and nutrients in relation to grazing pressure and soils in the Sandveld and Hardveld communal grazing areas of Botswana. *African Journal of Range and Forage Science* **22**: 17–28.

O'Connor, T.G. and Roux, P.W. 1995. Vegetation changes (1949-71) in a semi-arid, grassy dwarf shrubland in the karoo, South Africa: influence of rainfall variability and grazing by sheep. *Journal of Applied Ecology* **32**: 612–626.

Perkins, J.S. and Thomas, D.S.G. 1993. Spreading deserts or spatially confined environmental impacts: land degradation and cattle ranching in the Kalahari Desert of Botswana. Land Degradation and Rehabilitation **4**: 179–194.

Pople, A. and Page, M. 2002. Management of Artificial water points on national parks in Western Queensland. Ecology Centre, University of Queensland. School of Natural and Rural Systems Management.

Reitalu, T., Purschke, O., Johansson, L.J. Hall, K., Sykes, M.T. and Prentice, H.C. 2012. Responses of grassland species richness to local and landscape factors depend on spatial scale and habitat specialization. *Journal of Vegetation Science* **23**: 41–51.

SANBI. 2011. *Themeda triandra* Forssk. South African National Biodiversity Institute, South Africa.

SAS. 2001. SAS Institute Inc. Cary, NC USA.

Smet, M. and Ward, D. 2005. A comparison of the effects of different rangeland management systems on plant species composition, diversity and vegetation structure using grazing gradients around water-points in a semi-arid savanna. *African Journal of Range and Forage Science* **22**: 59–71.

Smet, M. and Ward, D. 2006. Soil quality gradients around water-points under different management systems in a semi-arid savanna, South Africa. *Journal of Arid Environment* **64**: 251–269.

Solomon, T., Snyman, H.A. and Smit, G.N. 2007. Rangeland dynamics in Southern Ethiopia: Botanical composition of grasses and soil characteristics in relation to land use and distance from water in semi-arid Borana Rangelands. *Journal of Environment Management*, in press, **85 (2007):** 429–442

Tainton, N.M., Edwards, P.J. and Mentis, M.T. 1980. A revised method for assessing veld condition. *Proceedings of the Grassland Society of Southern Africa* **15**: 37–42.

Tefera, S.B., Dlamini, B.J. and Dlamini, A.M. 2010. Soil nutrients and grass species structure in relation to land management systems and soil classes in the semi-arid Lowveld rangelands. *Journal of Arid Environments* **74**: 675–684.

Tefera, S. 2013. Rangeland degradation in semi-arid Swaziland: effects of dip-tanks on herbaceous vegetation and soil properties. *African Journal of Range and Forage Science.* 2013: 1–14

ter Braak, C.J.F. and Šmilauer, P. 2002. CANOCO reference manual and user's guide to

Canoco for Windows: software for canonical community ordination (version 4.5). Ithaca, New York: Microcomputer Power.

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

Tomlinson, K.W., Hearne, J.W. and Alexander, R.R. 2002. An approach to evaluate the effect of property size on land-use options in semi-arid rangelands. *Ecological Modelling* **149**: 85–95

Trollope, W. S. W. 1990. Veld management with specific reference to game ranching in the grassland and savanna areas of South Africa. *Koedoe* **33(2)**: 77–86.

van der Westhuizen, H.C., Snyman, H.A. and Fouche, H.J. 2005. A degradation gradient for the assessment of rangeland condition of a semi-arid sourveld of southern Africa. *African Journal of Range and Forage Science* **22**: 47–59.

van Oudtshoorn, F.P. 1999. Guide to grasses of South Africa. Second edition, First impression. Briza Publications. Cape Town, South Africa.

van Oudtshoorn, F.P. 2012. Guide to grasses of South Africa. Third revised edition, First Impression 2012. Briza Publications. Cape Town, South Africa.

van Rooyen, N., Bezuidenhout, D., Theron, C.K. and Bothma, J.Du.P. 1990. Monitoring of vegetation around artificial watering points (windmills) in the Kalahari Gemsbok National Park. *Koedoe* **33**: 63–88.

Victor, J., Siebert, S., Hoare, D. and Van Wyk, B. 2005. Sekhukhune land grasslands: a treasure house of biodiversity. Biodiversity, Policy and Planning, National Botanical Institute.

Vorster, M. 1982. The development of the ecological index method for assessing veld condition in the Karoo. *Proceedings of the Grassland Society of Sothern Africa* **17**: 84–89.

Wesulsa, D., Pellowskia, M., Suchrowb, S., Oldelanda, J., Jansenc, F. and Dengler, J. 2013. The grazing fingerprint: Modelling species responses and trait patterns along grazing gradients in semi-arid Namibian rangelands. *Ecological Indicators* **27**: 61–70.

World Atlas. 2012. Kwezana populated place (Accessed 01 March 2012) http://www.chinci.com/travel/pax/q/985100/Kwezana/ZA/South+Africa/0/

CHAPTER 4: Woody vegetation composition and structure in relation to different land management systems and distance gradients from water points.

ABSTRACT

This study examined the structure and distribution of woody vegetation around water points across three land management systems located in different environments. Twelve artificial water points, four each in two communal areas, two commercial ranches and two game reserves were selected. Woody vegetation surveys were conducted at 25, 50, 100, 200, 300 and 500 m from each water point. A total of 41 woody plant species were identified in all study areas. *Acacia karoo, Coddia rudis* and *Ehretia rigida* were the most dominant woody species. Tree equivalent (TE) density of all encroaching woody plants combined was significantly ($P < 0.05$) higher on the communal area (1732 TE ha-1) than the commercial ranches (1136 TE ha-1) and game reserves (857 TE ha-1), but with no marked variations along distance gradients from water points under all the land management systems. The population of seedlings (>0 – 1m) and saplings (>1 – 2m) were significantly ($P < 0.05$) greater in the communal sites (1730 no.ha^{-1}) than the commercial ranches (1135 no.ha^{-1}) and game reserves (1004 no.ha^{-1}). Mature trees (>3m) densities were lowest in the communal areas. Response along distance gradient from water points differed with land management systems. In the communal lands, greater proportions of seedlings were recorded at 50 m from water points. In the ranches, this occurred at 200 m from the water points. In the game reserve seedlings did not respond to this distance gradient. Both saplings and mature shrubs did not form piosphere around water points in all land management systems. The tree densities showed greatest population within 50 m in the ranch and farther away in the game reserve. The population of *A. karoo*, seedlings and saplings responded to season showing significantly higher densities in winter than summer. Many measured variables showed differences between farms or reserves of the same land management systems, and also between water location within a farm or reserve. Farmer's perceptions indicated that about nine identified species had no fodder values for livestock and game animals, and only one species had no traditional value. This study concluded that woody encroachment is not a problem in all studied areas. Differences abiotic, biotic and management between land management systems may be the cause for differences between these land management systems.

Key words: woody density, height class distribution, bush encroachment

4.1. Introduction

Woody plants are perennial plants including trees, shrubs or lianas which produce wood as their structural tissue. In most savannas and thicket biomes of the world, woody plants form the most important vegetation components of the ecosystem next to grasses. The roles of woody plants vary from providing feed, shade and shelter to animals to maintaining the ecosystem functions and services through soil enrichment and protection, maintenance of soil water balance, provision of habitats for diverse animals and plants, and utilities to mankind. Indeed, the functions and roles of woody plants to maintain the integrity and stability of an ecosystem depend on the woody species abundance, total cover, density and size groups distribution. It has been reported by previous researchers that over the past many decades, changes in the density, cover and biomass of individual and/or total woody plant species have occurred in many rangeland ecosystems of the world. When the change is upward, and significant to cause imbalance in the ecosystem, it is referred to as bush encroachment or invasion.

Reports that discuss the mechanism and causes of change in woody plant population in arid and semi-arid rangelands are many, but no conclusive or comprehensive theories have been developed. Several researchers (van Auken, 2000; Smit, 2004; Solomon *et al*., 2007) agreed that the increase in woody plant density appears to result from a gradual thickening of the local stands of one or few species (Knapp *et al*., 2008), while other suggest that this can also happen as the result of invasions by species foreign to an area (van Auken, 2000; Krug *et al*., 2010). Some (Johnston, 1963; van Vegten, 1983) believed that the change in the density of woody plants in semi-arid rangelands resulted from recent and rapid changes in the structure and abundance of woody species within their historic ranges, while others argued that this change occurred as the result of gradual expansions over many years (Norton-Griffiths, 1979; Dublin 1995). Under normal conditions, both small and large scale spatial distribution of woody plants in semi-arid environments are affected by climatic, topographic and edaphic factors. Changes and rate of changes in the total woody plants population and the relative proportion of species depend on fire, climatic and anthropogenic factors and their interactions with the physical environments.

Most of the changes in density of woody plants in many grasslands and savannas of the world have been associated with the introduction of cattle and cattle grazing systems (Bartolome, 1993; Archer *et al*., 1995; van Auken, 2009). Coetzee *et al*. (2008) postulated "the overgrazing theory" which states that sustained heavy grazing reduces above and belowground grass biomass, leading to increased resource availability for the establishment and recruitment of woody seedlings. This results in a concomitant reduction in fire frequency and intensity and therefore, allowing heavy stands of woody plants to gradually develop (van Auken, 2009). The formation of heavy stands, however, depends on land management and use decisions (van Auken, 2000), climatic, soil (Tefera *et al*., 2007; Beyene, 2013) and topographic regimes (Khuroo *et al*., 2011).

Although there is no conclusive evidence, changes in precipitation patterns or temperature may be linked to changes in the woody vegetation population (van Auken, 2000). Increased woody plant density has been reported to result from increased levels of atmospheric CO_2 and N deposition (Archer, 2010; van Auken, 2000). Here, the core hypothesis is based on the observations that most woody plants have the C_{-3} photosynthetic pathway which at higher levels of CO_2 (Ehleringer, 2005) are able to respond better in photosynthesis and water-use efficiencies and grow faster to easily alter the distribution of resources against the herbaceous vegetations. Indeed, the consequence of long-term high levels of CO_2 exposure is probably dependent on temperature, precipitation, herbivore disturbances, and land management (Shaw *et al*., 2005). Different from this view, some reports (van Auken, 2000) argued that changes in woody plant density may not be related to increased levels of atmospheric CO_2.

Although all these factors contribute to changes in the woody component in the grasslands and savanna ecosystems, the mechanisms involved as well as the rates and successional processes are not clearly understood, and their influences could also vary from one region to another (van Auken, 2000; Ward, 2002, 2005). The Eastern Cape Province of South Africa is the second largest province in landmass in South Africa with the terrestrial vegetation dominated by grasslands and savannas. The majority of the land is used for domestic animal production under communal, commercial and game reserve production systems. Eastern Cape is also characterized by a wide range of climate, topography and soils. Relatively few studies have investigated the spatio-temporal distribution of woody vegetation at local and large scale land management levels, and how this is influenced by climate, land management and physical environments and their interaction.

A better understanding of the factors driving the woody vegetation is essential to manage rangeland ecosystems on a sustainable basis because changes in woody plants population may also be associated with general disturbance in ecosystem functions, services and processes (van Auken, 2000, 2009; Archer, 2010). This study aimed to distinguish the abiotic (i.e. climate, topography, soil) and anthropogenic (land management, stocking rate, herd management) drivers for woody vegetation dynamics at local and large scale land management levels. By so doing, it contributed to the concept of determinants of vegetation changes. Knowledge of the current status of woody plants is needed to make any decision on control or conservation of woody species. The objectives of this study were therefore to investigate the effect of land management systems and water points on density and structure of woody plants.

4.2. Material and methods

4.2.1. Description of the study area

This study was conducted in the savannas of the Eastern Cape province of South Africa. The mean maximum and minimum temperature in summer varies between 15°C and 26.3°C and in winter 8°C to 18.4°C of the selected sites (World Atlas, 2012). The three main vegetation types in the study areas are Bisho Thronveld which is under Savanna biome; Great Fish Thicket and Eastern Cape Escarpment both of which fall under Albany Thicket biome (Mucina and Rutherford, 2011). The study area is fully discussed in section 3.2.1.

4.2.2. Site selection and transect layout

Two communal grazing areas, two commercial ranches and two game reserves were selected for this study. Two water points were selected from each farm and reserve. At each water point, two 500m straight transects were established on either sides starting from the watering point. Each transect was sub-divided into sub-transects at 25m, 50m (considered as near sites) 100m, 200m (middle sites), 300m and 500m (far sites) from the water point. At each distance a 10m x 10m plot was marked centering the transect line to record woody vegetation data. For the details of site selection and transect layout see section 3.2.2.

4.2.3. Data collection

All rooted live woody plants species were counted within each plot to determine the total woody plant density and density by species. Multistemmed plants were considered single if the distance between the stems was < 400 mm (Tefera *et al.*, 2007). A calibrated aluminum rod of 2 m long was used to measure height at lowest browsable material (LBM) and total plant height of individual plants. Based on their height, woody plants were grouped into the following size classes: Seedlings (≤ 1m); young shrubs (> 1–2 m); young trees or mature shrubs (≥ 2–3 m) and mature trees (> 3 m). Woody plant data were standardized to tree equivalent (TE) ha^{-1} (1 TE = 1 tree, 1.5 m high) (Teague *et al*., 1981). Information on vernacular names, browsing potential and other values of identified woody plants was gathered from communal farmers and commercial rangers. Data were collected in winter (May - July) and summer (November - January) seasons of 2012/2013.

4.3. Statistical analysis

Woody vegetation data were analysed using a General Linear Model (GLM) of SAS. For data that do not require analysis, simple descriptive statistics were employed where appropriate.

4.4 Results

A total of 40 woody plants were identified in all the study sites. Indeed, there were several other woody species which were not recorded because they did not fall in the study plots. Of the identified woody species, 11 were classified as trees, 13 were shrubs and others could fall into either group (Table 4.1). Ten of the total woody species were regarded as common to all sites. These included *Acacia karoo, Coddia rudis, Maytenus capitata, Ehretia rigida, Grewia robusta, Rhus refracta, Scutia myrtina, Rhus longispina, Aloe ferox* and *Maytenus polycantha*. Common woody species in this context are defined as those species recorded in several of the study plots of each land use systems.

Table 4.1. Scientific and vernacular name, growth forms, browse values and other traditional uses of woody plants identified in the study areas.

Scientific Names	Growth Forms	Vernacular Names	Values as Browse	Other traditional Use
Accacia karoo	T	Umnga	Goats, cattle, sheep and game	Firewood, fencing posts for cattle kraals, tough rope from inside bark. Good fodder tree. The thorns can also be used as needles. Bark and leaves: used to remedy diarrhoea in goats, treat intestinal parasites in goats, sheep, poultry and pigs.
Aloe ferox	S/T	Ikhala	Unacceptable	Juice from leaves can be used to treat typhoid, ticks and lice in poultry, red water in cattle, red water, and intestinal worms. Communal people generate income by selling the juice from leaves to middlemen. Its juice used to treat wounds and stomach ache in people.
Asparagus setaceus	S/T	Umvane	Unacceptable	Its leaves are crushed to treat wounds in human beings and have got edible fruits.
Azima tetracantha	S	Igcegceleya	Game	Herb to treat cough, asthma, diabetes, diarrhea and arthritis. Bark used to treat wounds in human beings and has edible fruits. Used as disinfectant for snake bite and chase away bad evil spirit.
Boscia oleoides	T	Umgqomo-gqomo	Cattle: results in unpleasantly tainted milk	Leaves are burnt on embers and the fumes inhaled to treat a cold and for vomiting.

Brachylaena elliptica	T	Isiduli	Goats	Poles from this species are used as fence posts. The sticks have been used to start a fire by friction. The leaves are believed to treat diabetes and stomach ache. Serves as windbreak and hedge. Boil leaves with water to wash dogs to remove mites.
Buddleja saligna	T	unGqeba	Unacceptable	Leaves to treat coughs and colds, woody is very fine is used to make small pieces of furniture. Straight branches used to make fence posts, good fuel wood.
Carissa haematocarpa	S	Isabetha-Nkunzi	Goats, cattle and game	Stick used to shake “isilawu” and its edible fruits induce libido in men.
Coddia rudis	S	Intsinde	Goats, cattle, sheep and game	Edible fruits; used to make kraals very strong; used as firewood.
Cussonia spicata	T	Umsenge	Goats, cattle and game	During drought farmers chop its leaves for feeding their livestock because it’s very tall. Bark used to retain placenta in stock, for convulsions, heart pains and gall sickness in cattle. Soft wood used to make mole traps as well as brakes block for ox wagons.
Diospyros lycioides	T	Umbhongisa	Unacceptable	The wood is durable and used to build huts and to make spoons. Decoction of roots is ingested to get rid of internal parasites such as worms. It is valued for its shade and shelter, but it is said to taint the milk of cows. Produce reddish fruits which are good and eaten by

				herders.
Diospyros scabrida	S/T	Umbhongisa	Unacceptable	Produce reddish fruits which are good and eaten by herders.
Ehretia rigida	S/T	Umhleli	Goats, cattle and game	Roots used to treat gall sickness in cattle fractures. Roots are powdered to treat small cuts in the skin. It brings luck to hunters and protects huts and crops from hail. Hunters use branches to make hunting bows and fishing baskets because they are strong and flexible; firewood. Has edible fruits eaten by herders.
Euclea undulata	S/T	Umgwari	Cattle, goats, sheep and game	Used for firewood, joinery as well as for fence posts. Infusion of the roots is used as medicine for heart disease and headaches. Windbreak and edible fruits.
Grewia occidentalis	S/T	Umnqabaza	Goats, cattle and game	Leaves used to treat gall sickness in stock; Its wood is used to make walking sticks and assegai handles. The bark is soaked in hot water and, is used to dress injuries; roots used to treat bladder problems as well as assist in childbirth. Has got edible fruits.
Grewia robusta	S/T	Umnqayi	Goats, cattle and game	Its wood is used as a stick by new men "iminqayi" from mountains (circumcision) and has got edible fruits.
Jasmine species	S	uSwazi	Unacceptable: poisonous	Roots are sometimes ingredients in love charm emetics. Medicine for kidney and stomach ailments. It climbs other woody plants.

Jatropha curcas	S/T	Unknown	Unacceptable (high tannin levels).	Seeds are soaked for constipation in cattle and goats.
Lantana camara	S	Ukutya kwentaka	Toxic to cattle and sheep, but not toxic to horses.	Extracts used to protect cabbage against the plant lice; used as herbal medicine and in some areas as firewood and mulch; planted as a hedge to contain or keep out livestock in some countries. Has got edible fruits.
Leucas capensis	S	Uphiphiyo	Unacceptable	Leaves used to treat gall sickness in stock; also, leaves are soaked to pour in aching ears in human beings.
Lycium ferocissimum	S	Umbovu	Unacceptable	Edible fruits and dogs like to urinate over this tree.
Maytenus capitata	S/T	Umqaqoba	Game and goats	Used to make kraals and for firewood.
Maytenus heterophylla	S	Umqaqoba	Game and goats	Firewood and making kraals.
Maytenus polyacantha	S/T	Umqaqoba	Game and goats	Firewood and making kraals.

Olea Africana	T	Umnquma	Cattle, goat and game	Put its leaves in dishes with meat in traditional ceremonies.
Opuntia ficus-indica	Fruit crop	Sablayi	Unacceptable	It's is poisonous but have edible sweet fruits, called tunas.
Ozoroa paniculosa	T	Isifuku	Browsed by elephant and black rhino	Bark and root bark to treat abdominal problems in animals e.g. diarrhoea, red water, sweating sickness. Powdered bark from this tree is used to treat acute inflammation in the chest.
Pappea capensis	T	iliTye or umGqalutye	Cattle, goat, sheep and game animals.	Leaves, bark and the oil extracted from the seed are used medicinally against baldness, ringworm, nosebleeds, chest complaints, eye infections, and venereal disease. Also used to make strong sticks "induku".
Phyllanthus Verrucosus	S	Impingelo	Goats and Cattle	Boil its leaves then use water to wash to protect for protection in evil spirit.
Plumbago auriculata	S	Umatshini-tshini	Unacceptable	Used as hedge, soaked leaves and use water to wash face to be soft. Its burnt and its smoke remove evil spirit "ukuqhunyiswa". Used also to heal evil pig lice in human beings.
Portulacaria afra	S	Igwanishe	Cattle, goat, sheep and	Leaves treat stomach ache. Astringent juice is used for soothing ailments of the skin such as pimples, rashes and insect stings.

			game animals, tortoises	
Prickly pear	Fruit Crop	Itolofiya	Baboon	Treat wounds. Its fruit is edible and people harvest it and sell it in roads for income.
Ptaeroxylon obliquum	S/T	Umthathi	Browsed by game.	Its smoke prevents lightning. Used for ritual purposes. Bark is used as a snuff to relieve headaches. Cause mucosal inflammation to those who work with the wood.
Rhus longispina	S/T	Umchani	Cattle, goats and game	Wood is used to make implement handles for axes and fencing posts. Ripe fruit is edible. Its dried fruit is used to make tea. This tree is important in traditional medicine.
Rhus lucida	S	Amapozi	Cattle, goats and game	Firewood and edible fruits for human beings and birds.
Rhus refracta	S	Intlolokotshane	Cattle, goats and game	Firewood and edible fruits for human beings and birds.
Rhigozum obovatum	S/T	Unknown	Cattle, goats and game.	No value
Schotia afra	T	Umnqonci	Browsed by game animals	Used to make tighten sticks “intonga”

Scutia myrtina	S/T	Isiphingo	Cattle, goat and game	Has got black edible berries.
Ziziphus mucronata	T	Umphafa	Cattle, goat and game animals.	Put in graves to protect them from animals.

4.4.1. Density and structure of woody plants

4.4.1.1. Variations in relation to land management systems

Results of woody plant density of the three land use systems are presented in Table 4.2. Total woody plant density was statistically higher (<0.0001) in the communal land than the ranches and the game reserves. *Acacia karoo* and *C. rudis* are the two woody plants which were more abundant in the communal lands than the ranches or game reserves. The densities of *R. longispina* and *A. ferox* were highest at the ranch, while *S. myrtina* was significantly denser in the game reserves. All the other woody species were related to the ranch and game reserve sites (Table 4.2). Regarding size, both seedlings (>0-1m) and saplings (>1-2m) were significantly more abundant in the communal than the game reserve or ranches. Mature shrubs and/or young trees (>2-3m) had similar densities in all land management systems. However, mature trees (>3m) were more abundant in the ranch and game reserves than the communal areas (Table 4.4).

Table 4.2. Density of total and common woody plants in relation to land use (TE ha^{-1})

Woody plants	**Land use**			**SEM**	**Significance**
	Com	**Game**	**Ranch**		
Acacia karoo	869^a	232^b	363^b	45.8	<0.0001
Coddia rudis	116^a	79^b	34^c	11.4	<0.0001
Maytenus capitata	9^b	59^a	39^a	1.62	<0.0030
Ehretia rigida	2^b	67^a	48^a	0.84	<0.0001
Grewia robusta	0^b	58^a	35^a	1.37	<0.0001
Rhus refracta	0^b	48^a	32^a	1.22	<0.0001
Scutia myrtina	24^b	50^a	23^b	1.05	<0.0005
Rhus longispina	0^b	18^b	47^a	1.28	<0.0462
Aloe ferox	3^b	3^b	83^a	0.77	<0.0016
Maytenus polycantha	2^b	31^a	13^a	0.81	<0.0347
Total woody plant density	1070^a	823^b	933^{ab}	60.4	<0.0001

^{a,b,c} Means in the same row with different superscripts are significantly different ($p < 0.05$). SEM = standard error of means.

4.4.1.2. Variations in relation to site and water point location

Season didn't show any significant effect ($p > 0.05$) on seedlings of all woody species, except of those of *A. karoo* which showed significantly higher ($p < 0.05$) quantity in summer than winter. This also caused the total woody plants to be higher ($p < 0.001$) in summer than winter (Table 4.3). Except *S. myrtina*, *R. longispina* and *A. ferox*, all other woody species varied greatly in density between farms or reserves within each land management system. Similarly, total woody plant density also showed significant differences ($p < 0.01$) between farms or reserves. Only the densities of four woody species (*C. rudis*, *M. capitata*, *G. robusta* and *S. myrtina*) showed marked differences at small scale land units (i.e. between water points) within each farm (Table 4.3). Considering size classes, only seedlings and saplings were significantly affected by season with summer having greater densities than winter. The densities of all size classes, except mature trees appeared to vary between farms or reserves within each land management system. The densities of seedlings ($p = 0.06$) and mature trees ($p < 0.05$) showed also significant variations within small land units between water locations.

Table 4.3. F and P-values of woody plant densities in relation season, sites (between farms or reserves) and location (between water points) and distance from water-points within each site.

Plant density	**Between season**		**Between sites**		**Between water-points within sites**	
	F	P	F	P	F	P
Accacia karoo	6.0	0.0150	9.6	0.0022	2.2	0.1408
Coddia rudis	0.2	0.6898	4.8	0.0300	38.3	0.0001
Maytenus capitata	2.5	0.1155	10.0	0.0018	6.9	0.0090
Ehretia rigida	0.2	0.6924	12.7	0.0004	2.9	0.0884
Grewia robusta	0.3	0.5775	38.8	0.0001	5.4	0.0214
Rhus refracta	3.5	0.0629	36.5	0.0001	0.3	0.6012
Scutia myrtina	0.1	0.7159	0.2	0.6403	10.3	0.0015
Rhus longispina	0.9	0.3439	1.9	0.1675	0.04	0.8328
Aloe ferox	1.1	0.2982	0.2	0.6234	0.01	0.9373
Maytenus polycantha	1.7	0.2006	6.6	0.0108	0.03	0.8638
Total woody plant density	16.2	0.0001	8.5	0.0038	0.9	0.3545

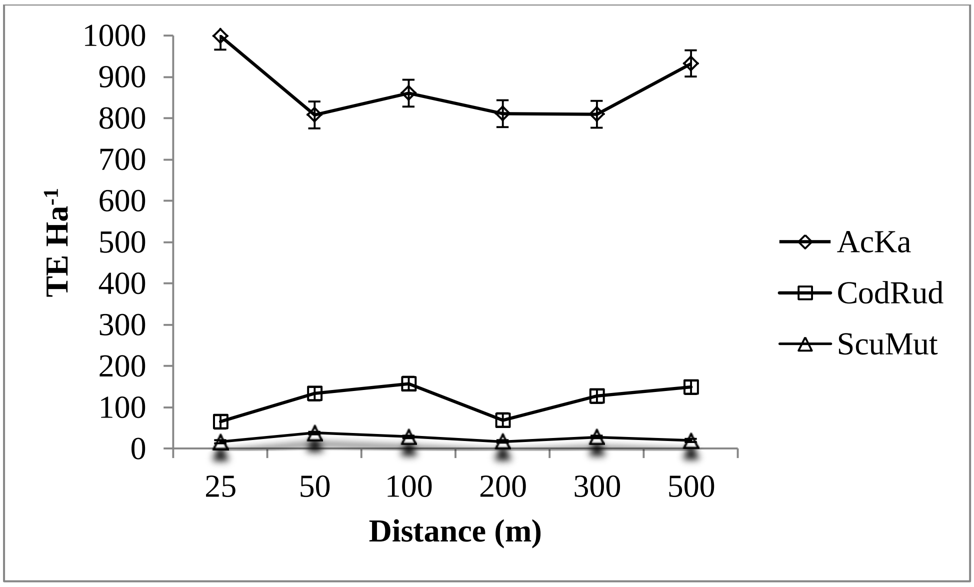


Figure 4.1a. Density of common woody species (TE ha^{-1}) in relation to distance from water point in communal areas (*AcKa-Acacia karoo; CodRud- Codia rudis; ScuMut-Scutia myrtina*).

4.4.1.3. Response to distance from water points

In the communal areas, there was no significant response of *A. karoo* and *S. myrtina* populations to distance gradient from water, but the *C. rudis* showed lowest density at 25 and 200m, and highest density at 100 and 500m from the water point (Figure 4.1a). In both game reserves and ranch, the population of common woody plant species showed significant differences between distances but did not display increasing or decreasing trends in moving away from the water points (Figure 4.1b and c). Total woody plant density did not vary with distance away from water points in the communal and commercial ranches (Figure 4.2), but in game reserves, the highest density was found at 50m from water point (Figure 4.2).

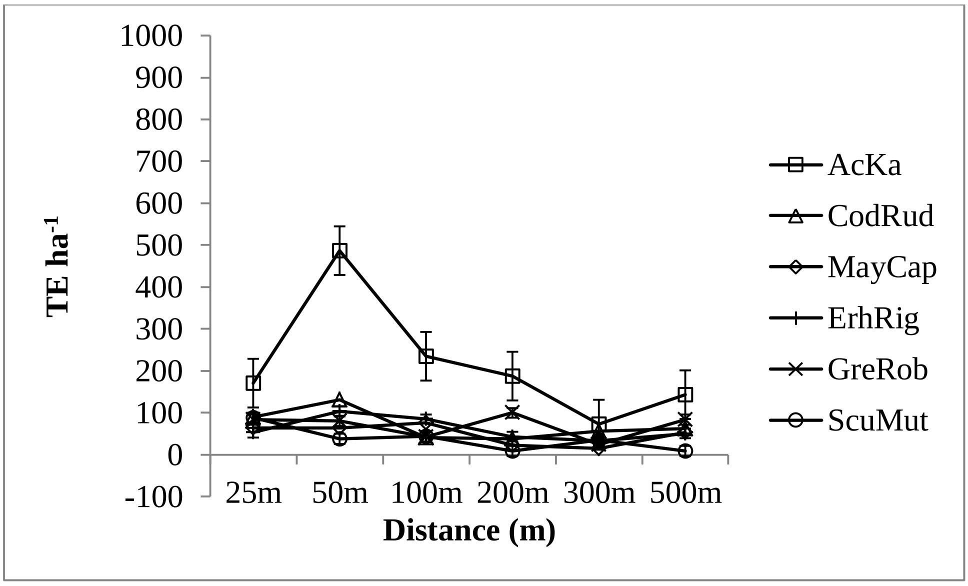


Figure 4.1b. Density of common woody species (TE ha^{-1}) in relation to distance from water point in game. *MayCap-Maytenus capitata; ErhRig-Eritia rigida; GreRob-Grewia robusta.*

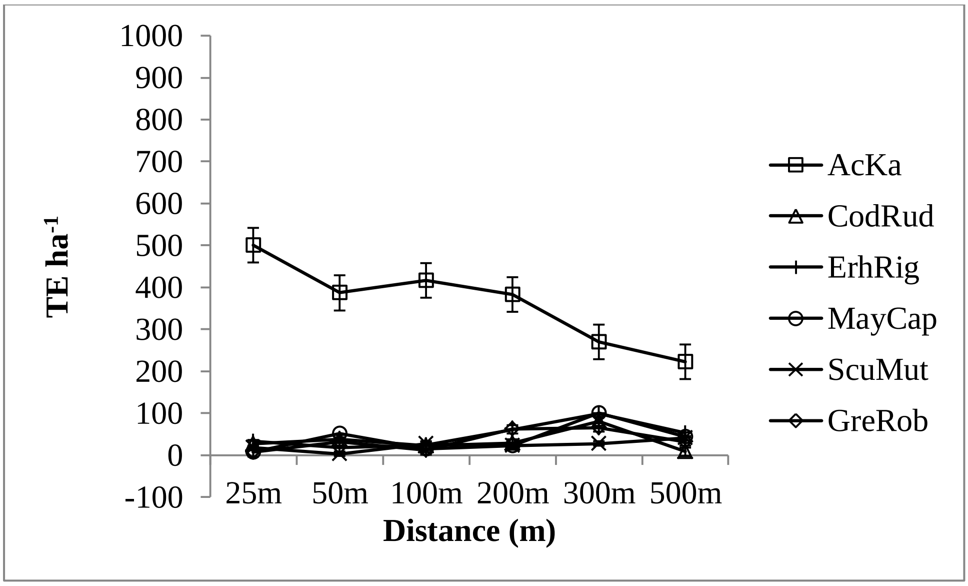


Figure 4.1c. Density of common woody species (TE ha^{-1}) in relation to distance from water point in commercial ranches.

Results on height class distribution showed that in the communal areas, the highest populations of seedlings were found at 50 and 500 m from the water points, which saplings and mature shrubs densities did show neither significant differences nor trends in distance away from water points. The population of trees varied between distances but without any clear trends (Figure 4.3a). In the ranch, the highest densities of seedlings and tree sizes occurred at 200 and 50 m from water points, but the other size groups had statistically similar densities throughout the distance (Figure 4.3b). In the game reserves, except the tree densities which had highest values at the far sites, all other size groups were not significantly affected by distance gradient from water (Figure 4.3c).

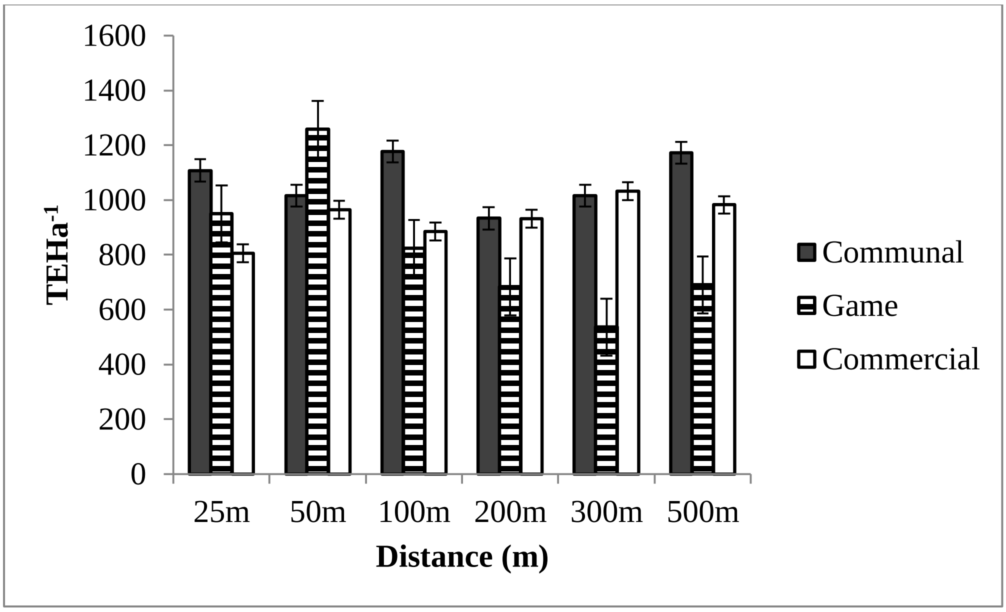


Figure 4.2. Total woody plant density (TE ha^{-1}) in relation to distance from water point in communal areas, commercial ranch and game reserves.

4.4.2. Uses of woody plants

Table 4.1 presents the forage and traditional uses of woody plants which is important to know the value of the available woody plants. According to the opinion of the communal elders, 67.5 per cent of the total woody plants had forage values to livestock and game species. Only five species namely; *A. karoo, C. rudis, E. undulata, P. capensis* and *P. afra* were preferred by the all species (sheep, goat, cattle and game). Only one species is preferred by goats only, one species by cattle only, five species by game only and one species by goats and cattle.

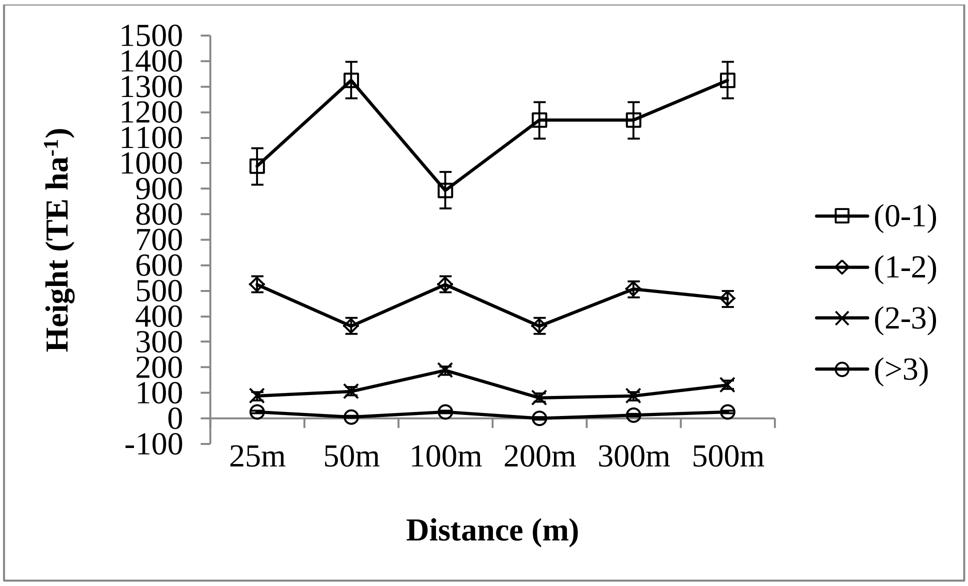


Figure 4.3a. Height class distribution in relation to distance from water point in communal areas.

About 12 woody species are browsed by cattle, goats and game, three species by game and goats. Also, 12 woody species were unacceptable to all animal species found in those areas. No woody species were preferred by goats and sheep, cattle and sheep or sheep alone, and cattle and game animals together. The values of woody plants for other traditional purposes are also presented in Table 4.1. Accordingly, 38 plant species have traditional roles. These include firewood (eight species), fencing and construction (five species), medicinal values for livestock and people (21), and for human food were 14 species. Other traditional roles include use for traditional rituals and funeral occasion. Almost all woody plants identified have multiple roles.

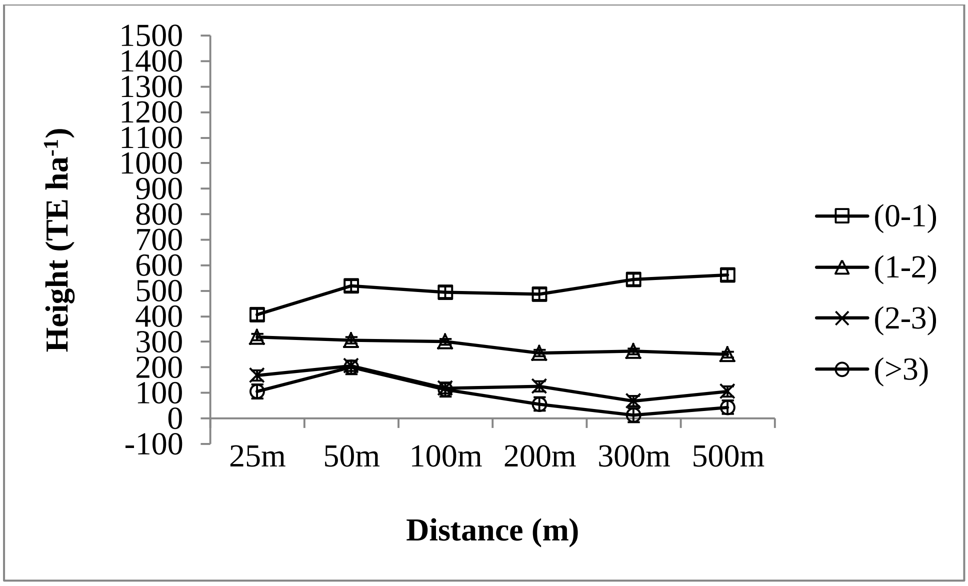


Figure 4.3b. Height class distribution in relation to distance from water point in game reserve

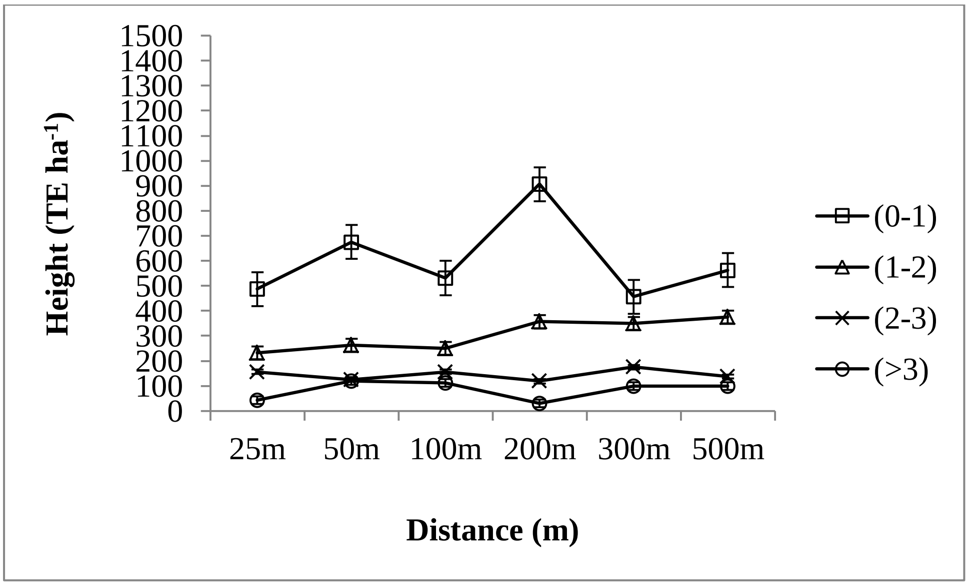


Figure 4.3c. Height class distribution in relation to distance from water point commercial ranches.

Table 4.4. Height class distribution (No ha^{-1} (%)) among different land use systems in the study areas

Height Class	Land use			SEM	Significance
	Com	Game	Ran		
0 - 1	1144.8^{a} (66%)	502.1^{b} (50%)	603.1^{b} (53%)	56.3	<0.0001
1 - 2	458.3^{a} (27%)	282.3^{b} (28%)	304.2^{b} (27%)	32.2	<0.0001
2 - 3	113.5^{a} (7%)	132.3^{a} (13%)	144.8^{a} (13%)	15.2	<0.0001
>3	15.6^{b} (1%)	88.5^{a} (9%)	84.4^{a} (7%)	10.3	<0.0001

[a,b] Means in the same row with different superscripts are significantly different (P < 0.01). SEM = standard error of means.

Table 4. 5. F and p-values of woody plant densities in relation to season, sites (between farms or reserves) and location (between water points) and distance from water-points within each site.

Height Class (m)	Between season		Between sites		Between water-points within sites	
	F	P	F	P	F	P
0 - 1	6.9	0.01	11.12	0.01	2.06	0.06
1 – 2	3.29	0.08	5.78	0.02	1.06	0.31
2 – 3	0.93	0.34	13.37	0.01	1.19	0.28
>3	0.39	0.53	0.04	0.84	5.26	0.03

4.5 Discussion

Some of the woody species identified in this study were similar to previous studies in the same ecology though there were some differences in the report of their relative abundance. For instance, Lesoli (2008) similarly reported that *C. rudis* and *A. karoo* occurred abundantly in similar study areas, but did not report *M. capitata, E. rigida, G. robusta, R. refracta, S.*

myrtina, R. longispina, A. ferox and *M. polycantha* as common species. Moreover, Mapuma (2000) similarly reported that *A. karoo, S. myrtina* and *C. rudis* occurred abundantly in similar study areas, but *Maytenus heterophylla, Cussonia spicata, Diospyros lyciodes* and *Grewia occidentalis* were reported in the current study as non-dominating woody species.

4.5.1. Diversity and structure of woody plants

4.5.1.1 Variation in relation to land management systems

In this study, total woody plant density in the communal lands appeared similar to the commercial ranches but significantly higher than game reserves. For most parts, the communal and commercial ranches have similar soils, rainfall and topographic features including altitudes. However, these factors show difference between the communal (soil-loamy; rainfall-500-900mm, and altitude: 561-656 m) and the game ranches (soil-clay; rainfall-300-600mm, and altitude 415 & 816-916 m). Therefore, this suggests that woody density differences below the encroached level may be primarily influenced more by abiotic factors than land use history, management and/or livestock pressure.

The result of this study indicates that bush encroachment is not a problem in all land management systems. Literature stated that woody plant density of 2400 ha^{-1} regarded as borderline between non-encroached and encroached condition in African Savannas (Roques *et al*., 2001). However, density of 2500 TE ha^{-1} was considered as highly encroached condition in Southern Africa rangelands (Richter *et al*., 2001). The higher woody density found in the communal areas compared to the game agreed with the studies of Smet and Ward (2005) from North Cape of South Africa and Gandiwa *et al*. (2013) from Zimbabwe, but both authors concluded the cause to be high stock density in the communal areas. In contrast, substantial increase in bushes for the three land use systems were reported in Hluhluwe area in Kwazulu-Natal of South Africa, with the communal land-the least severely affected (Wigley, 2006). Unlike the current study, advancement of bush encroachment has been reported in many semi-arid regions of Southern Africa. Hudak and Wessman (2001) reported a 30% increase in woody plant cover between 1955 and 1996 for Madikwe Game reserve, South Africa. Roques *et al*. (2001) investigated that woody plant encroachment increased from approximately 3% to over 40% in 50 year in South African communal rangelands. Beyene (2013) also reported a high bush cover in the communal grazing lands of Swaziland surrounding dip-tanks.

Although all woody species were recorded in all land management systems, their distribution varies greatly. *Acacia karoo* was identified as the most abundant and frequently occurring woody species in all the land management systems. High proportion of *A. karoo* was found in communal areas than other land management systems. This may not be caused not only by abiotic factors but also by the presence of many abandoned crop lands in communal grazing areas that provide favorable environment for the recruitment of this species. *Acacia karoo* has been reported as one of the most common encroaching woody plants in the semi-arid savannas of the Eastern Cape Province (Aucamp, 1976).

Higher abundance of *C. rudis* and *A. karoo* in Eastern Cape rangelands was similarly reported by (Lesoli, 2008). Both *C. rudis* and *A. karoo* tolerate the effect of strong wind and also survive long periods of drought and high temperatures without extra water (Pooley, 1993), and therefore have the ability to spread in unfavorable environment and management conditions. Raimondo *et al.* (2009) reported that leaves of *C. rudis* are heavily browsed by game animals, and this may be the reason for its less density in the game reserves.

Considering size class, the densities of seedlings and saplings were more abundant in communal than game and ranches. The primary causes for these differences may be abiotic (between communal and game) or anthropogenic (between communal and ranches). This study partially agrees with the study of Tefera *et al*. (2007) who reported higher and lower densities of saplings and seedlings in southern Ethiopia rangelands. The dominance of small shrubs in rangelands was reported in many savanna rangelands in Africa (Van Vegeten, 1981, Friedel, 1985; Solomon *et al*., 2007). Mature trees (>3m) were more abundant on the commercial ranch and grazing reserve than communal. This is probably due to the fact that, at the game reserve and ranches, the farmers might have kept some of the trees to provide shade to the animals.

4.5.1.2 Variations in relation to season, site and water points location

Season didn't affect densities of all woody species, except on *A. karoo* which showed significantly higher density in summer than winter. This also caused the total woody plants to be higher in summer than winter (Table 4.3). Considering size classes, only seedlings and saplings were significantly affected by season with summer having greater densities than winter. Possible explanation which may be given to this are that 1) in summer, there may be more germination of seeds and seedlings recruitment of *A. karoo* and less browsing pressure. Bulk and concentrate grazers of both livestock and wild species may tend to forage from herbaceous layer in summer compared to winter, and 2) In winter, herbaceous forage resources become scarce and so, both grazers and browsers may tend to increase their relative browse intake from seedlings and young woody plants and this may eventually kill these plants.

It has been well documented that *A. karoo* is one of the most browsed forage by both domestic and wild animals (Pitta, 2007). Contrary to the current findings, the study of Ganqa *et al*. (2005) documented a higher density of *A. karoo* in winter in Double Drift game reserves of South Africa. The authors explained that wild ungulates preferred to browse other woody species such as *P. auriculata* to *A. karoo* in winter. Except S. *myrtina, R. longispina* and *A. ferox*, all other woody species were greatly varied in density between farms and/or reserves within each land management system. Similarly, total woody plant density showed also significant differences ($P < 0.01$) between farms or reserves. The densities of all size classes, except mature trees also appeared to vary between farms or reserves within each land management system. Differences between the two game reserves may be explained by the abitoic variations including altitude and rainfall and by the size of the farms. Both reserves have similar game species and stocking rates. Differences between the communal areas may be attributed mainly be the variations in stocking rates of both main grazers and browsers as the two communal areas shows similarity in terms of soil, altitude and rainfall, animal species and farm size. Differences between the ranches may be explained strongly by stocking rates, animal species and farm size and partly by abiotic variations. Wesulsa *et al*. (2013) reported abiotic differences between sites and different stocking rates were expected to bias the response patterns of some species with weak response signals leading to neutral responses because of the strict model selection framework in Namibian rangelands. Only the densities of four woody species (*C. rudis, M. capitata, G. robusta* and *S. myrtina*) showed marked differences at small scale land units (i.e. between water points) within each farm and this may be related to habitat preference of plants within a small scale area.

4.5.1.3. Response to distance from water points

There were no clear trends in the total densities of woody plants around watering points, but there were signs of highest densities at the middle and far in communal lands, in near and far on commercial ranches and only near in game reserves. Unlike these findings, Smet and Ward (2005) from South Africa and Tefera *et al*. (2007) from southern Ethiopian rangelands reported that density of the woody plants also did not differ significantly along a distance gradient from water points.

Results of the height class distribution were inconsistent among the land use systems but generally showed no gradients around the water points. Similarly, Tefera *et al*. (2007)

considered that the land-use systems, density in the height class of >0–0.5m did not differ significantly between the three land-use systems while others did, however along the distance gradient from water also showed no gradients around water points. *Acacia karoo* is the only dominant species that showed highest density in the vicinity of water points. This could be due to high grazing pressure by livestock which reduce biomass and basal cover and lead to an increase of *A. karoo*. Moreover, *A. karoo* has a long taproot which enables it to use water and nutrients from deep underground and out competing grass species (Van Wyk and Van Wyk, 1997).

4.5.2 Use of woody plants

Farmer's perceptions indicated that about nine identified species had no fodder values for livestock and game animals (*A. ferox*, *A. setaceus*, *B. saligna*, *D. lycioides*, *D. scabrida*, *J. species*, *J. curcas*, *L. capensis*, *O. ficus-indica*, *P. auriculata*), and only one species (*R. obavatum*) had no traditional value. This implies that woody plant species identified in this study are very important to farmers due to their acceptability to their livestock and game animals. Moreover, identified woody species showed a great importance when about all of them they have traditional value which is also vital to farmers especially to treat their livestock.

4.6 Conclusion

In conclusion, this study indicates the absence of high density and structure that is, low bush encroachment which is mainly caused by long-term use of water points in the form of vegetation changes due to high grazing pressure. This study concluded that vegetation indicators such as woody density and height class distribution are able to show browsing impact around water-points. High proportion of *A. karoo* and high densities of seedlings and saplings in the current study could seem as good indicators of changes in woody vegetation composition and structure in relation to different land management systems and distance gradient from water points. Response along distance gradient from water points differed with land management systems. In the communal lands, greater proportions of seedlings were recorded at 50 m from water points. In the ranches, this occurred at 200 m from the water points. In the game seedlings did not respond to this distance gradient. Both saplings and mature shrubs did not form piosphere around water points in all land management systems. The densities showed greatest population within 50 m in the ranch and farther away in the game reserve. The population of *A. karoo*, seedlings and saplings responded to season showing significantly higher densities in winter than summer. Many measured variables showed differences between farms or reserves of the same land management systems, and also between water location within a farm or reserve. The population of seedlings (>0 – 1m) and saplings (>1 – 2m) were significantly ($P < 0.05$) greater in the communal sites (1730 no.ha^{-1}) than the commercial ranches (1135 no.ha^{-1}) and game reserves (1004 no.ha^{-1}). Mature trees (>3m) were lowest in the communal areas. Farmer's perceptions indicated that about nine identified species had no fodder values for livestock and game animals, and only one species had no traditional value. This study concluded that woody encroachment is not a problem in all studied areas. Differences in abiotic, biotic and management between land management systems may be the cause for differences between these land management systems.

REFERENCES

Archer, S.R., Schimel, D.S. and Holland, E.H. 1995. Mechanisms of shrubland expansion: land use, climate or CO2. *Ecology Applied* **29:** 91–99.

Archer, S.R. 2010. Rangeland conservation and shrub encroachment: new perspectives o an old problem. In: Wild Rangelands: Conserving Wildlife While Maintaining Livestock in Semi-arid Ecosystems (eds Toit, J.T.d., Kock, R. & Deutsch, J.C.). John Wiley and Sons Ltd, Chichester, UK, pp. 53–97.

Aucamp, A.J. 1976. The role of the browser in the bushveld of the Eastern Cape, *Proceedings of the Annual Congresses of the Grassland Society of Southern Africa*, **11 (1)**: 135–138.

Bartolome, J.W. 1993. Application of herbivory optimization theory to rangelands of the Western United States. *Ecology Applied* **3:** 27–39.

Beyene, S.T. 2013. Rangeland degradation in a semi-arid communal savannah of Swaziland: long–term dip-tank use effects on woody plant structure, cover and their indigenous use in three soil types. Land Degradation and Development. Africa *Journal of range and forage sciences*.

Coetzee, B.W.T., Tincani, L., Wodu, Z. and Mwasi, S.M. 2008. Overgrazing and bush encroachment by Tarchonanthus camphoratus in a semi-arid savanna. *African Journal of Ecology* **46:** 449–451.

Dublin, H.T. 1995. Vegetation dynamics in the Serengeti-Mara ecosystem: the role of elephants, fire, and other factors. In: Sinclair ARE and Arcese P (eds) Serengeti II: Dynamics, Management, and Conservation of an Ecosystem. University of Chicago Press, Chicago, USA. pp 71–90.

Ehleringer, J.R. 2005. The influence of atmospheric CO2, temperature, and water on the abundance of C3/C4 taxa. In: Ehleringer, J.R., Cerling, T.E., Dearing, M.D. (Eds.), A History of Atmospheric CO2 and Its Effects on Plants, Animals, and Ecosystems. Springer, New York, pp. 214–231.

Friedel, M.H. 1985. The population structure and density of central Australian trees and shrubs and relationships to range condition, rabbit abundance and soil. *Australian Rangeland Journal* **7**: 130–139.

Gandiwa, P.Z., Mabika, C.T., Kupika, O.L., Gandiwa, E., and Murungweni, C. 2013. Vegetation Structure and Composition across Different Land Uses in a Semiarid Savanna of Southern Zimbabwe. Hindawi Publishing Corporation. *International Journal of Biodiversity*. Vol. 2013, Article ID 692564, 5 pages.

Ganqa, N.M., Scogings, P.F., and Raats, J.G. 2005. Diet selection and forage quality factors affecting woody plant selection by black rhinoceros in the Great Fish River Reserve, South Africa. *South African Journal of Wildlife Research* **35(1)**: 77–83

Hudak, A.T. and Wessman, C.A. 2001. Textural analysis of high-resolution imagery to quantify bush encroachment in Madikwe Game Reserve, South Africa, 1955-1996. *International Journal of Remote Sensing* **22**: 2731–2740.

Johnston, M.C. 1963. Past and present grasslands of southern Texas and northeast Mexico. *Ecology* **44**: 456–466

Khuroo, A.A., Weber, E., Malik, A.H., Reshi, Z.A. and Dar, G.H. 2011. Altitudinal distribution patterns of the native and alien woody flora in KashmirHimalaya, *Indian Environmental Research* **111**: 967–977.

Knapp, A.K., McCarron, J.K., Silletti, G.A., Hoch, G.l., Heisler, M.S., Lett, J.M., Blair, J.M., Briggs, J.M., Smith, M.D. 2008. Ecological consequences of the replacement of native grassland by Juniperus virginiana and other woody plants. In: van Auken, O.W. (Ed.), Western North American Juniperus Communities: A Dynamic Vegetation Type. Springer, New York, pp. 156–169

Krug, R.M., Roura-Pascual, N. and Richardson, D.M. 2010. Clearing of invasive alien plants under different budget scenarios: using a simulation model to test efficiency. *Biology Invasion*. **12**: 4099–4112.

Lesoli, **M. S.** 2008. Vegetation and soil status, and human perceptions on the condition of communal rangelands of the Eastern Cape, South Africa. MSc Thesis, University of Fort Hare.

Mapuma, M. 2000. Soil, herbaceous and woody response to different methods of bush control in a Mesic Eastern Cape Savanna. MSc Thesis. University of Natal.

Mucina, L. and Rutherford, M.C. (eds). Reprint 2011. The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South Africa National Biodiversity Institute, Pretoria.

Norton-Griffiths, M. 1979. The influence of grazing, browsing and fire on the vegetation dynamics of the Serengeti. In: Sinclair ARE and Norton-Griffiths M (eds) Serengeti: Dynamics of an Ecosystem. University of Chicago Press, Chicago, Illinois, USA. pp 310–352

Pitta, J. 2007. Indigenous Plants of South Africa, 2007, Briza Publications, p87

Pooley, E. 1993. The complete field guide to trees of Natal, – Zululand and Transkei. Natal Flora Publications Trust, Durban.

Raimondo, D., Von Staden, L., Foden, W., Victor, J.E., Helme, N.A., Turner, R.C., Kamundi, D.A. and Manyama, P.A. (eds). 2009. Red List of South African plants 2009. Strelitzia 25. South African National Biodiversity Institute, Pretoria.

Richter, C.G.F., Snyman, H.A. and Smit, G.N. 2001. The influence of tree density on the grass layer of three semi-arid savanna types of Southern Africa. *African Journal of Range Forage Science* **18**: 103–109.

Roques, K.G., O'Connor, T.G., and Watkinson, A.R. 2001. Dynamic of shrub encroachment in an African savanna: Relative influences of fire, herb ivory, rainfall and density dependence. *Journal of Applied Ecology* **38**: 268–280.

Shaw, M.R., Huxman, T.E. and Lund, C.P. 2005. Modern and future semi-arid and arid ecosystems. In: Ehleringer, J.R., Cerling, T.E., Dearing, M.D. (Eds.), A History of Atmospheric CO2 and Its Effects on Plants, Animals and Ecosystems. Springer, New York, pp. 415–440.

Smet, M. and Ward, D. 2005. A comparison of the effects of different rangeland management systems on plant species composition, diversity and vegetation structure in a semi-arid savanna. *African Journal Range Forage Science* **22**: 59–71.

Smit, G.N. 2004. An approach to tree thinning to structure southern African savannas for long-term restoration from bush encroachment. *Journal of Environmental Management* **71**: 103–109

Solomon, T., Snyman, H.A. and Smit, G.N. 2007. Rangeland dynamics in Southern Ethiopia: Botanical composition of grasses and soil characteristics in relation to land use and distance from water in semi-arid Borana Rangelands. *Journal of Environment Management*, in press **85 (2):** 429–442.

Teague, W.R., Trollope, W.S.W., Aucamp, A.J. 1981. Veld management in the semi-arid bush grass communities of the Eastern Cape. *Proceedings of the Grassland Society of South Africa* **16:** 23–28.

Tefera, S. Snyman, H. A. Smit, G. N. 2007. Rangeland dynamics of southern Ethiopia: (2). Assessment of woody vegetation structure in relation to land use and distance from water in semi-arid Borana rangelands. *Journal of Environment Management* **85 (2)**: 443–452.

van Auken O.W. 2000. Shrub Invasions of North American Semiarid Grasslands. *Annual Review of Ecology and Systematics* **31**: 197–21.

van Auken, O.W. 2009. Causes and consequences of woody plant encroachment into western North American grasslands. *Journal of Environmental Management* **90**: 2931–2942

van Vegeten, J.A. 1981. Man-made Vegetation Changes: An Example from Botswana's Savanna. National Institute Development Cultural Research, Gaborobne. Pp. 78–81.

van Vegeten, J.A. 1983. Thornbush invasion in a savanna ecosystem in eastern Botswana. *Vegetation* **56**: 3–7.

van Wyk, B. and van Wyk, P. 1997. Field Guide to Trees of Southern Africa. Struik Publishers. Cape Town.

Ward, D. 2002. Do we understand the causes of bush encroachment in African savannas? In: Seydack AHW, Vorster T, Vermeulen WJ and Van der Merwe IJ (eds) Multiple Use Management of Natural Forests and Woodlands: Policy Refinements and Scientific Progress. Natural Forests and Woodlands Symposium III. Department of Water Affairs and Forestry, Berg-en-Dal, South Africa. pp 189–201.

Ward, D. 2005. Do we understand the causes of bush encroachment in African savannas? *African Journal of Range and Forage Science* **22**: 101–105.

Wesulsa, D., Pellowskia, M., Suchrowb, S., Oldelanda, J., Jansenc, F. and Dengler, J. 2013. The grazing fingerprint: Modelling species responses and trait patterns along grazing gradients in semi-arid Namibian rangelands. *Ecological Indicators* **27**: 61–70.

Wigley, B.J. 2006. Investigating bush encroachment under different land use practices in South African Savannas. *Proceedings of the 41st Annual Congress-Grassland Society of Southern Africa*, July 17-21, 2006, Bela, South Africa, pp: 1-1.

World Atlas. 2012. Kwezana populated place (Accessed 01 March 2012) http://www.chinci.com/travel/pax/q/985100/Kwezana/ZA/South+Africa/0/

CHAPTER 5: Soil physical and chemical properties in relation to different land management systems and distance gradient from water points.

ABSTRACT

This study investigated the physical and chemical properties around water points in three land management systems. Twelve artificial water points, four each in two communal areas, two commercial ranches and two game reserves were selected. Two long transects were established in each water point and divided into sub-transects at 25, 50, 100, 200, 300 and 500, and five top soil samples with 20 cm depth were collected at 100 m^2 plots laid in each sub-transect. Soil samples were analyzed to determine the physical (soil organic matter (SOM) and bulk density) and chemical properties. Soil compaction was also measured in each transect. Soil pH and bulk density did not vary between the land management systems, while electrical conductivity (EC), SOM and soil compaction did being highest in the game reserve. Highest compaction ($P < 0.05$) was recorded in the communal sites followed by the ranch. The three variables also differed significantly ($P < 0.05$) between distances from water points but without increasing or decreasing trend. The EC was significantly ($P < 0.01$) higher in game reserves than in communal grazing areas and ranches. Soil organic matter percentage showed greatest and lowest values in the game and ranches respectively. Soil properties were affected by herbivore pressure and trampling around water points with inconsistence magnitude and direction. Soil quality along distance gradient from water points was affected by livestock and game animal pressure and trampling around water points. The objectives of this study were therefore to investigate the effect of land management systems and water points on soil physical and chemical properties.

Key words: Soil condition, soil quality, soil erosion, trampling

5.1. Introduction

For several decades, rangelands have been subjected to external intervention in order to support animal production. These interventions include provision of kraals, feeders, dipping tanks, and artificial sources of water (Tefera *et al*., 2007). Watering points are focal points of grazing by domestic and some native wild animals in rangelands. Concentrations of relatively large numbers of domestic and wild animals around watering points, particularly over summer, create gradients of degradation across the landscape. However, the magnitude of trampling and its associated degrading effects such as replacement of desirable plant species by less desirable ones (Fusco *et al*. 1995; Todd, 2006).

Grazing intensity decreases with distance to the watering point, resulting in an increase in the relative grazing intensity towards the watering point (Todd, 2006). Nash *et al*. (2003) stated that changes across grazing gradients include changes in species composition, diversity and richness, soil compaction, changes in surface roughness, soil erosion, alterations to the normal flow of surface water, and reduction in vegetation cover of perennial plants. According to Andrew (1988), many of these changes could become irreversible and may lead to substantial reductions in ecosystem functions such as soil nutrient cycling and infiltration rate. The development of artificial water points may change the vegetation distribution and soil properties within a certain radius from the water points and in severe cases may have degradative effects on the surrounding ecosystem. Nevertheless, relatively few studies have examined the soil properties in relation to land management systems and disturbance gradients along water points. The objectives of this study were therefore to investigate the effect of land management systems and water points on soil physical and chemical properties.

5.2. Material and methods

5.2.1. Description of the study area

This study was conducted in the savannas of the Eastern Cape province of South Africa. The mean maximum and minimum temperature in summer varies between 15°C and 26.3°C and in winter 8°C to 18.4°C (World Atlas, 2012). The three main vegetation types in the study areas are Bisho Thornveld which is part of the Savanna biome; Great Fish Thicket and Eastern Cape Escarpment both of which fall under the Albany Thicket biome (Mucina and Rutherford, 2011). The study area is fully discussed in 3.2.1.

5.2.2. Site selection and transect layout

Two communal grazing areas, two commercial ranches and two game reserves were selected for this study. Two water points were selected from each farm and reserve. At each water point, two 500m straight transects were established on either sides starting from the watering point. Each transect was sub-divided into sub-transects at 25 m, 50 m (near sites) 100 m, 200 m (middle sites), 300 m and 500 m (far sites) from the water point. At each distance a 100 m^2 plot was marked centering the transect line to record woody vegetation data. For the details of site selection and transect layout see section 3.2.2.

5.2.3 Soil Sampling and analysis

Topsoil samples within a depth of 20 cm were collected from each plot at 5 random locations using a soil auger or spade for soil clods within each plot. Each set of samples from each plot was mixed in one paper bag to make composite samples. Soil samples were weighed fresh and oven dried at 105°C for 24 hours to get gravimetric moisture content (Black, 1965). Some oven dried soil samples were placed at 450°C for six hours in a muffle furnace to determine the soil organic matter contents by the loss on ignition method (David, 1988).

Soil pH was measured with a combined electrode pH meter in 2.5:1 water (ml) to soil (g) suspension as described by Okalebo *et al*. (2002). Electric conductivity (EC) was measured in the saturated paste extract after resting it for 1 hour (Bray and Kurtz, 1945). The saturated paste method is used to determine soil EC, where same sample allowed settling for one hour then measuring the conductivity of the supernatant liquid.

An estimate of soil compaction was obtained from 20- point measurements conducted randomly in each sub-transect with a simple rod penetrometer (Friedel, 1987) along animal drinking points, that is, at 25 m, 50 m, 100 m, 200 m, 300 m and 500 m. Soil compaction readings were taken to a depth of 0 - 4.5 mm. Points were placed 1 m apart on two parallel lines spaced by 2 m. The length of each line was 10 m. Values obtained were then compared with 20 point measurements from an animal foot path. Soil compaction measurements were taken about 24 hours after at least 25 mm of rain had fallen.

5.2.4 Statistical Analysis

Soil physical and chemical data were analyzed using a General Linear Model (GLM) of SAS. For data that do not require analysis, simple descriptive statistics were employed where appropriate.

5.3 Results

5.3.1 Soil pH, EC and Organic matter in different land management systems

There was no significant effect ($p > 0.01$) of land management on soil pH around animal drinking water points (Table 5.1). The EC was significantly ($p < 0.01$) higher in game reserves than in ranch. Soil organic matter percentage showed greatest and lowest ($p < 01.01$) values in the game reserves and ranches respectively. Soil bulk density was not affected ($p > 0.05$) by land management systems (Table 5.1). Moreover, soil compaction (% cattle path) showed lowest ($p < 0.01$) value in the game and highest in the communal sites as shown in Table 5.1.

Table 5.1. Soil pH, EC, bulk density, soil compaction (% cattle path) and organic matter among different land management systems.

Land management	Soil pH	EC (mS/cm)	OM (%)	Bulk density (g/cm^3)	Soil Compaction (g/cm^3)
Communal	6.02[a]	43.56[b]	3.69[ab]	1.45[a]	85.58[a]
Game	9.36[a]	184.32[a]	3.94[a]	1.28[a]	70.24[c]
Ranch	6.28[a]	55.77[b]	3.34[b]	1.31[a]	76.01[b]

[a, b] Mean values with different superscripts within the same column are significantly different ($p < 0.05$). ANOVA: p-value = 0.0444 (OM); p-value = 0.4076 (pH); p-value <0.0001 (EC); p-value < 0.0001 (Soil compaction); p-value <0.0001 (bulk density).

5.3.2 Soil pH, EC and Organic matter among different sites

The soil pH was similar ($p > 0.001$) in all sites (Table 5.2). Soil pH, EC, SOM, soil compaction and bulk density showed no significant effect ($p > 0.001$) in communal areas. However, between game reserves EC, SOM, soil compaction and bulk density showed significant variation ($p < 0.001$). Moreover, only SOM and soil compaction showed significant effect ($p < 0.001$) between commercial ranches (Table 5.2).

Table 5.2. Soil pH, Soil EC, soil compaction (% cattle path) bulk density and Organic matter among different sites

Site	pH	EC (mS/cm)	OM (%)	Soil compaction (g/cm^3)	Bulk density (g/cm^3)
Upper Gqumashe	6.02^{a}	44.93^{c}	3.49^{bc}	86.60^{a}	1.50^{a}
Kwezana	6.02^{a}	42.18^{c}	3.90^{b}	84.67^{a}	1.39^{ab}
Double-Drift	6.18^{a}	100.19^{b}	3.32^{bc}	74.05^{bc}	1.33^{b}
Mpofu	9.22^{a}	268.46^{a}	4.57^{a}	67.53^{d}	1.23^{c}
Honeydale	6.06^{a}	30.33^{c}	3.76^{b}	78.65^{b}	1.29^{bc}
Glen-Muir	6.50^{a}	81.20^{bc}	2.92^{c}	72.49^{c}	1.33^{b}

$^{a,\ b,\ c}$ Mean values with different superscripts within the same column are significantly different. ANOVA: p-value < 0.0001 (OM); p-value < 0.0001 (EC); p-value = 0.4872 (pH); p-value <0.0001 (soil compaction); p-value < 0.0001 (bulk density).

Table 5.3. Effect of distance from water points in relation to soil parameters in three land management systems

Distance from water points	pH	EC (mS/cm)	OM (%)
25m	6.11^{a}	79.95^{b}	3.72^{ab}
50m	9.18^{a}	96.48^{ab}	3.73^{ab}
100m	6.06^{a}	75.49^{b}	3.50^{ab}
200m	6.09^{a}	82.89^{b}	3.71^{ab}
300m	6.07^{a}	142.51^{a}	4.01^{a}
500m	5.99^{a}	89.96^{ab}	3.30^{b}

$^{a,\ b}$ Mean values with different superscripts within the same column are significantly different ANOVA: p-value = 0.437 (OM); p-value = 0.4031(pH); p-value = 0.2204 (EC)

5.3.3 Soil ph, EC and Organic matter along distance gradient from water points

There was no significant difference ($p > 0.05$) in pH along the gradient to water points. However, the pH was highest at 50 m and lowest at 500 m (Table 5.3). The EC didn't show any significant ($p > 0.05$) effect in all marked distances from water points except in 300 m which had high value than others ($p < 0.05$). OM was similar along distance gradient from water points between 300 m and 500 m in all sites. Soil compaction percentage showed a slightly significant ($p < 0.001$) difference with no trend along distance from water point in the communal and game (Figure 5.1). Also, between communal and game soil compaction (% cattle path) showed a low significant difference with no increasing or decreasing trend in some distance from water points as shown in Fig. 5.1 below. Moreover, soil compaction (% cattle path) showed a very slightly significant effect between ranch and game with no trend in some distance from water points (Fig. 5.1). Soil bulk density didn't show any significant ($p > 0.01$) effect and clearly trend along distance gradient from water points in all land management systems (Figure 5.2).

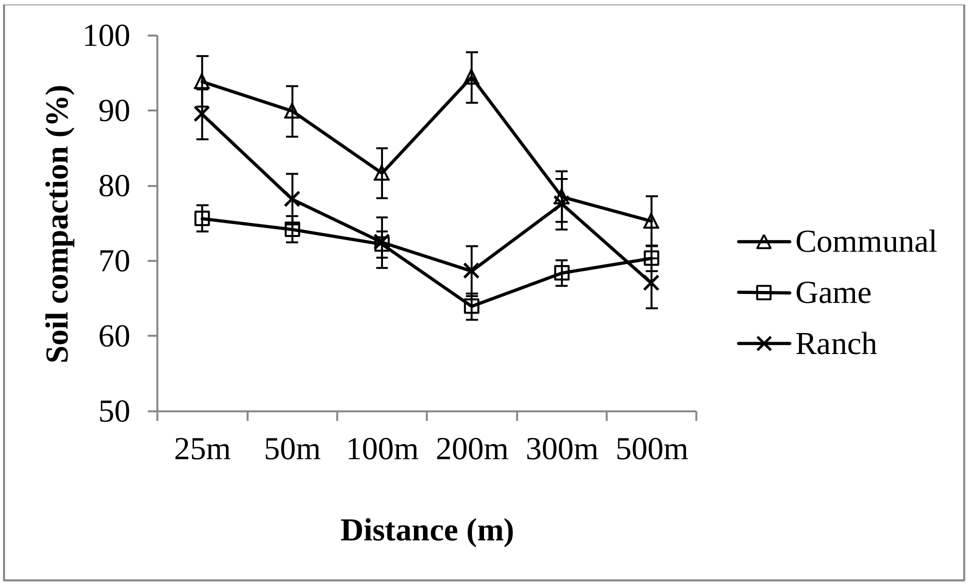


Figure 5.1. Soil compaction (% cattle path) along distance from water points in all land management systems

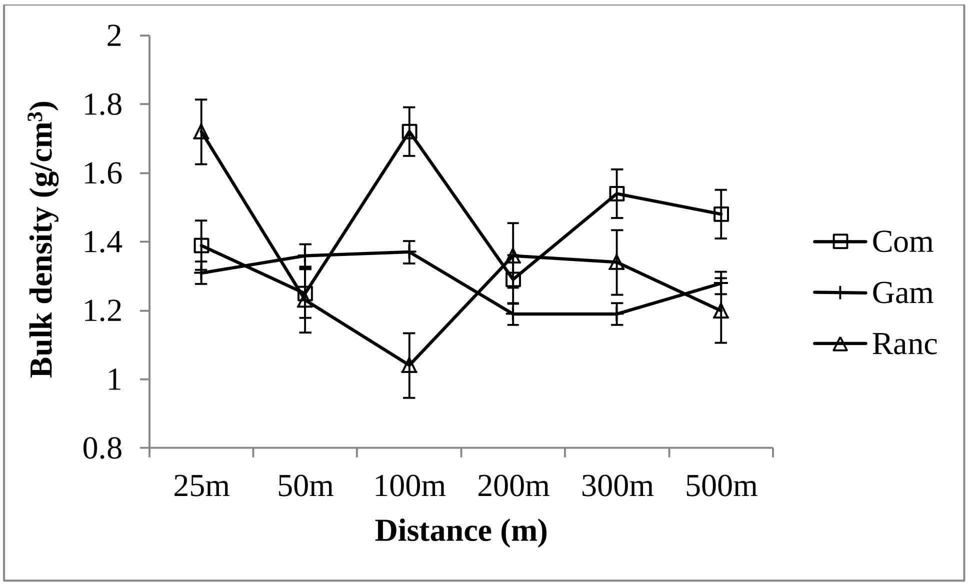


Figure 5.2. Soil Bulk density along distance gradient from water points in all land management systems

5.4 Discussion

5.4.1 Soil pH and EC in different land management systems, sites and distance gradients from water points

Concentrations of pH, OM and EC didn't show any trend in all land management systems, sites and distance gradient from water points. Soil pH is a function of parent material, time of weathering, vegetation and climate (Jeffrey *et al*., 2002). The results suggest that the pH did not vary between all land management systems, sites and along distance gradient from water points. This implies that different grazing practices in different land management systems did not have effect on soil pH. This observation was attributed to the similarities in herbivore grazing intensity, trampling, defection and urination. These results were supported by Tefera *et al*. (2010) who reported that the soil pH did not vary between land management systems and the soil types of Swaziland savannas. The findings of this study suggest a weak effect of herbivore activity on soil properties and nutrients around watering point in all land management systems as the soil was found to be alkaline. The absence of significantly different soil pH values in all land management systems, sites and along distance gradients from water points suggested that animal effects may be insufficient to cause influence soil pH, contrary to Killham (1994) and Zhao *et al*. (2007) who reported that herbivore grazing, trampling, defecation, and urination affected soil pH.

The EC values were higher in game reserve compared to the communal grazing areas and ranches. This result implied that different grazing practices in communal and ranches did not affect the concentration and distribution of the soil salinity whereas game reserve did. This implication could be attributed to soil physical properties of communal and ranches than land or vegetation types. In support of these results, Corwin *et al*. (2003) indicated that EC is influenced by bulk density. In all selected sites and distances from water points, overall patterns of soil EC were not clear and consistent, although a significantly higher value was noticed in both game reserves and in 50 and 300 m away from water points.

5.4.2 Organic matter among different land management systems, sites and distance gradient from water points

The organic matter content of the soils in all sites and along distance from water points varied from 2.9 to 4.5% for 0 to 20 cm depth of soil samples. The current findings found soil OM significantly low in ranches than game reserves, this could be due to some different management practices in both land management like in ranches fire is used to control bush encroachment. The above statement is supported by Bot and Benites (2005), who reported that management practices that alter the living and nutrient conditions of soil organisms, such as repetitive tillage or burning of vegetation, result in reduction of soil biota where there are no longer organisms to decompose soil organic matter and bind soil particles. All sites had high OM (>3.5%) except Glen-Muir ranch which had a low percentage (2.9%) had also the lowest stocking rate than other sites as stated in section 3.2.1, and clear evidence was not found to discuss this result. Soil OM didn’t show any increasing or decreasing trend between sites and along distance gradient from water points. It has been reported that high organic carbon near water-points is likely to be caused by centripetal movement (Smet and Ward, 2006). Smet and Ward (2006) reported that herbivores get most of their roughage from vegetation in the grazing areas and regular visit the water-point.

In the current study, OM was high (>3.5%) near water points with decreasing trend further away from water points in Game and Ranches, while communal didn't show any increasing or decreasing trend. Here they deposit organic matter through their faeces, therefore, high organic carbon percentage increases soil fertility (Stewart *et al*., 1987; Berg *et al*., 1997; Snyman, 1999) and affects soil pH (Killham, 1994). Soil organic carbon can buffer acidity and retain a neutral soil pH level (Bloom, 2000). The above statement support our findings where is shown that in 500m away from water points OM is lower than other distances and pH level is more acidic (Table 5.3).

5.4.3 Soil compaction and bulk density among different land management systems, sites and distance gradient from water points

The soil compaction was found significantly different among all land management with communal having high percentage of cattle path followed by ranches then game reserve as shown in Table 5.1. The bulk density didn't show any significant effect among land management systems, there higher its values, there higher those of soil compaction with communal having high followed by ranches then game reserve. The soil compaction and bulk density among land management systems varied from 70.2 to 85.6% and 1.28 to 1.45%, respectively, this implies that there is an existence of continued heavy grazing on the communal lands compared to other land management systems. These findings are in agreement with study of Smet and Ward (2005); Tefera *et al*. (2007) who reported that bare ground which result in compacted soil was far more common under the communal grazing lands than other two land-management. Kwezana and Upper Gqumashe had high significant effects in soil compaction and bulk density than other sites as similar as stated above under communal grazing land. Mpofu game reserve has less compacted soil and bulk density than Double-Drift sites. This could be due to the main difference between the reserves which is altitude. The literature states that areas with high altitudes receive more rainfall which can be the cause of less compacted soil and bulk density in Mpofu game reserve. Honeydale showed high compacted soil and bulk density than Glen-Muir ranch, this could be due to the differences between farms which encompasses both stocking rate (Glen-Muir having low stocking rate) and altitudes.

The presence of a positive significant correlation between the bulk density and soil compaction (% cattle path) illustrates that bulk density may contribute to the compaction of the soil due to the exposure of the soil to animal trampling, wind and water erosion. Herbivore grazing and trampling along distance gradient from water points in the present study affected soil resistance, because, soil found more compacted near water points and decreasing disturbance further away from the water-points. This is in agreement with Hao and Chang (2003) who reported that herbivore grazing, trampling, defecation, and urination can affect soil resistance. Also, Smet and Ward, (2005) supported current study when investigated that soil properties and nutrients showed disturbance near to the water points and decreasing disturbance further away from the water points. In contrast, many researchers investigated that in areas of heavy grazing, it is not only the cumulative weight of many animals that compacts the soil, but the destruction of soil macro-pores created by burrowing invertebrates and plant roots that reduces infiltration (Lobry de Bruyn and Conacher, 1990; Whitford *et al*., 1992; Greene *et al*., 1994). A benefit of accumulation of dung and urine from grazing herbivores close to the watering point is the nutritive input to soils and grasses leading to greater productivity (Georgiadis and McNaughton, 1990; Perkins and Thomas, 1993a), this is with agreement with the results found in the current study on grasses species composition where showed no difference along distance from water points in the current study. These results therefore gave us a good indication that herbivore activity did affect soil quality near water points.

5.5 Conclusion

Soil pH and bulk density did not vary between the land management systems, while electrical conductivity (EC), SOM and soil compaction did being highest in the game reserve. Highest compaction was recorded in the communal sites followed by the ranch. This implies that identical grazing practices at different land management systems types did not have effect on soil pH and bulk density. The EC was higher in game reserves than in communal grazing areas and ranches. Soil organic matter percentage showed greatest and lowest values in the game and ranches respectively. Soil properties were affected by herbivore pressure and trampling around water points with inconsistence magnitude and direction. Soil quality along distance gradient from water points was affected by livestock and game animal pressure and trampling around water points. In all sites soil pH value did not vary. Soil pH, EC, SOM, soil compaction and bulk density showed no significant effect in communal areas. However, between game reserves EC, SOM, soil compaction and bulk density showed significant variation with being highest value of EC and OM at Mpofu than Double Drift and higher values of soil compaction and bulk density at Double Drift than Mpofu game reserve. Moreover, only SOM and soil compaction showed variation between commercial ranches being highest in Honeydale than Glen Muir commercial ranches. Soil compaction, EC and SOM were only variables showed variation along distance gradient from water points. Further studies can be undertaken to investigate the effect of soil nutrients along distance gradient from water points in Eastern Cape savannas.

REFERENCES

Andrew, M.H. 1988. Grazing impact in relation to livestock watering points. *Trends in Ecology and Evolution* **3**: 336-339.

Berg, W.A., Bradford, J.A. and Sims, P.L. 1997. Long-term soil nitrogen and vegetation change on sandhill rangeland. *Journal of Range Management* **50**: 482–486.

Black C.A. 1965. "Methods of Soil Analysis: Part I Physical and mineralogical properties". American Society of Agronomy, Madison, Wisconsin, USA.

Bloom, P.R. 2000. Soil pH and pH buffering. In: Sumner, M.E. (Ed.), Handbook of Soil Science. CRC Press, Boca Raton, FL, pp. 333–352.

Bot, A. and Benites, J. 2005. The importance of soil organic matter Key to drought-resistant soil and sustained food production. Sales and marketing group Information Division Food and Agriculture Organization of the United Nations Viale delle Terme di Caracalla 00100 Rome, Italy

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Science* **59**: 39-46.

Corwin, D. L., Kaffka, S.R., Hopmans, J.W., Mori, Y., van Groenigen, J.W. and van Kessel, C. 2003. Assessment and field-scale mapping of soil quality properties of a saline sodic soil. *Geodema* **114**: 231-259.

David, M.E. 1988. Use of loss-on-ignition as an estimate of soil organic carbon in forest soils. *Common Soil Science Plant Analysis* **19**:1593-1599.

Friedal, A.H. 1987. A preliminary investigation of woody plant increase in the western Transvaal and implications for veld assessment. *Journal of Grassland Society of Southern Africa* **4 (1)**: 25-30.

Fusco, M.J., Holechek, J., Tembo, A., Daniel, A., Cardenas M. 1995. Grazing influence on watering point vegetation in the Chihuahuan Desert. *Journal of Range Management* **48**: 32-38.

Georgiadis, N.J. and McNaughton, S.J. 1990. Elemental and fibre contents of savanna grasses: variation with grazing, soil type, season and species. *Journal of Applied Ecology* **27**: 623-634.

Greene, R.S.B., Kinnell, P.I.A. and Wood, J.T. 1994. Role of plant cover and stock trampling on runoff and soil erosion from semi-arid wooded rangelands. *Australian Journal of Soil Research* **32**: 953-973.

Hao, X. and Chang, C. 2003. Does long-term heavy cattle manure application increase salinity of a clay loam soil in semi-arid southern Alberta? *Agriculture, Ecosystems and Environment* **94:** 89–103.

Jeffrey, L.S., Jonathan, J.H. and Harvey, B. Jr. 2002. Soil properties and microbial activity across a 500 m elevation gradient in a semi-arid environment. *Soil Biology and Biochemistry* **34**: 1749–1757.

Killham, K. 1994. Soil Ecology. Cambridge University Press, Cambridge.

Lobry de Bruyn, L.A. and Conacher, A.J. 1990. The role of ants and termites in soil modification: a review. *Australian Journal of Soil Research* **28**: 55-93.

Mucina, L and Rutherford, M.C. (eds). Reprint 2011. The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South Africa National Biodiversity Institute, Pretoria.

Nash, M.S., Jackson, E., Whitford, W.G. 2003. Soil microtopography on grazing gradients in Chihuahuan Desert grasslands. *Journal of Arid Environments* **55**: 181-192.

Okalebo, J.R., Gathua, K.W. and Woomer, P.L. 2002. Laboratory methods of soil and plant analysis: a working manual. TSBF Program UNESCO-ROSTA Soil Science Society of Eastern Africa Technical Publication No. 1. Nairobi: Marvel EPZ (Kenya).

Perkins, J.S. and Thomas, D.S.G. 1993a. Spreading deserts or spatially confined environmental impacts: land degradation and cattle ranching in the Kalahari desert of Botswana. *Land Degradation and Rehabilitation* **4**: 179-194.

Smet, M. and Ward, D. 2005. A comparison of the effects of different rangeland management systems on plant species composition, diversity and vegetation structure using grazing gradients around water points in a semi-arid savanna. *African Journal of Range and Forage Science* **22**: 59–71.

Smet, M.,Ward, D. 2006. Soil quality gradients around water-points under different management systems in a semi-arid savanna, South Africa. *Journal of Arid Environments* **64**: 251-269.

Snyman, H.A. 1999. Short-term effects of soil water, defoliation and rangeland condition on productivity of a semi-arid rangeland in South Africa. *Journal of Arid Environments* **43**: 47–62.

Stewart, J.W.B., Follett, R.F. and Cole, C.V. 1987. Integration of organic matter and soil fertility concepts into management decisions. In: Follett, R.F. (Ed.), Soil Fertility and Organic Matter as Critical Components of Production Systems. Soil Science Society of America Inc., Madison, pp. 1–8.

Tefera, S., Snyman, H.A. and Smit, G.N. 2007. Rangeland dynamics in southern Ethiopia: Botanical composition of grasses and soil characteristics in relation to land-use and distance from water in semi-arid Borana rangelands. *Journal of Environmental Management* **85**: 429–442

Tefera, S., Dlamini, B.J. and Dlamini, A.M. 2010. Changes in soil characteristics and grass layer condition in relation to land management systems in the semi-arid savannas of Swaziland. *Journal of Arid Environments* **74**: 675–684.

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

Whitford, W.G., Ludwig, J.A. and Noble, J.C. 1992. The importance of subterranean termites in semi-arid ecosystems in south-eastern Australia. *Journal of Arid Environments* **22**: 87-91.

Zhao, Y., Peth, S., Krummelbein, J., Horn, R., Wang, Z., Steffens, M., Hoffman, C. and Peng, X. 2007. Spatial variability of soil properties affected by grazing intensity in Inner Mongolia grassland. *Ecological Modelling* **205**: 241-254

CHAPTER 6: SUMMARY

6.1 General Discussion

The objective of the current study was to provide understanding on the level and extent of changes in vegetation and soil properties around water points. The effect of land management systems and water points on herbaceous species yield, composition, diversity and richness in communal, commercial and game reserve were investigated in Chapter 3. In Chapter 4, the effects of land management systems and water points on density and structure of woody plants distribution were investigated. Moreover, the effects of land management systems and water points on soil physical and chemical properties were examined in Chapter 5.

A total of 30 grass species were identified in all study areas. Of these, 23 species were strong perennials, three species were annuals and four species were weak perennials. About ten species of the total identified grasses were highly palatable, nine were moderately palatable, two were less palatable species and nine species were poorly palatable. Accordingly, of thirty (30) grass species identified, ten were classified as common or dominant species. In this study, although all grass species were recorded in all land use systems, their distribution varies greatly.

When species are grouped based on their forage value, the occurrences of highly palatable (HP) species were significantly higher in the ranch (46.1%), where the poorly palatable (PP) and less palatable (LP) species were lowest. Tefera (2013) concluded that such scenarios may highlight the presence of less herbivore pressure over the past and present grazing utilization. The significantly lower DM yield in the communal areas than the ranches may evidently suggest the presence of both short and long-term high herbivore utilization. In this study, the frequencies of all grass species, palatability groups and DM yield did not respond to distance gradient from water points. The length of transects could not go beyond 500 m due to the presence of fence lines and this may have a blurring effect on the piosphere pattern. Similarly, several studies conducted in semi-arid or arid environments reported the absence of variations in species abundance along a gradient from a focal point (Bonifica, 1992; Tefera *et al*., 2007a). In contrast, many studies indicated that herbaceous species respond to the piosphere effect around water points (Nsinamwa *et al*., 2005; Smet and Ward 2006; Todd 2006).

Total woody plant density in the communal lands appeared similar to the ranches but significantly higher than game reserve. The result of this study indicates that bush encroachment is not a problem in all land management systems. The higher woody density found in the communal areas compared to the game agreed with the studies of Smet and Ward (2005) from North Cape of South Africa and Gandiwa *et al*. (2013) from Zimbabwe, but both authors concluded the cause to be high stock density in the communal areas. Although all woody species were recorded in all land management systems, their distribution varies greatly. Higher proportion of *A. karoo* was found in communal areas than other land management systems. This may not be caused not only by abiotic factors but also by the presence of many abandoned crop lands in communal grazing areas provide favorable environment for the recruitment of this species *A. karoo*. This has been reported as one of the most common encroaching woody plant in Eastern Cape Savannas (Aucamp, 1976).

Considering size class, the densities of seedlings and saplings were more abundant in communal than game and ranches. The primary causes for these differences may be abiotic (between communal and game) or anthropogenic (between communal and ranches). This study partially agrees with the study of Tefera *et al*. (2007) in southern Ethiopia rangelands who reported higher and lower densities of saplings and seedlings, respectively. Season didn't affect densities of all woody species, except on *A. karoo* which showed significantly higher density in summer than winter due to harvesting for firewood by communal people.

There were no clear trends in the total densities of woody plants around watering points, but here were signs of highest densities at the middle or far (communal lands), at the near or far (ranches), and at near only (game reserves). Unlike these findings, Smet and Ward (2005) from South Africa and Tefera *et al*. (2007) from southern Ethiopian rangelands reported that density of the woody plants also did not differ significantly along a distance gradient from water points. Results of the height class distribution were inconsistent among the land management systems but generally showed no gradients around the water points

Concentrations of pH, OM and EC didn't show any trend in all land management systems, sites and distance gradient from water points. The results suggest that the pH did not vary between all land management systems, sites and along distance gradient from water points. This implies that different grazing practices in different land management systems did not have effect on soil pH. These results were supported by Tefera *et al*. (2010) who reported that the soil pH did not vary between land management systems and the soil types of Swaziland savannas. The EC values were higher in game reserve compared to the communal grazing areas and ranches. The current findings found soil OM significantly low in ranches than game reserve, this could be due to some different management practices in both land use like in ranches fire can be used to control bush encroachment. The above statement is supported by Bot and Benites (2005), who reported that management practices that alter the living and nutrient conditions of soil organisms, such as repetitive tillage or burning of vegetation, result in reduction of soil biota where there are no longer organisms to decompose soil organic matter and bind soil particles. The soil compaction was found significantly different among all land use with communal having high percentage of cattle path followed by ranches then game reserve. The bulk density didn't show any significant effect among land use systems.

Soil pH didn't show any effect around water points whereas; EC was significantly affected with no increasing or decreasing trend. Soil OM showed significant variations along distance gradient from water points in all land use with communal showing no trend, however, in game and ranches decreasing trend is observed from 25 - 100m away from water points. Soil bulk density is not affected around water points in communal and game with game having increasing trend from water points to 300m away, however, it is significantly affected in ranches with no trend. Lastly, soil compaction is slightly affected around water points in all land management systems.

6.2 Limitations of this research

This research was conducted to observe the vegetation and soil around water points in different land uses. Therefore, we expect soil and topographic heterogeneity among the land use systems, and this may limit statistical comparison of the three land use systems. Rainfall is variable due to differences in altitude values in the study areas and this could also affect our results. Summer rainfall in the current year is low and drought is expected. This might limit the identification of grasses and also the results may be flawed to a certain degree leading to repetition of the survey in the following year (2013). Dangerous wild animals in the game ranches will give difficulties during data collection if they are around. Incidence of refusal to use the lands by managers and any community members in the course of the study may occur. When such incidence occurs, other areas may be considered but this will undoubtly delay the data collection and hence the study period.

6.3 Conclusions

In conclusion, grass species composition and GDM did not significantly respond to distance from water points and this may explain that either grazing gradient was absent or the short length of transects as limited by the presence of fences was not enough to explain the absence or presence of gradients. High proportions of *A. karoo* and high densities of seedlings and saplings in the current study found as good indicators of the woody vegetation composition and structure in relation to different land management systems and distance from water points. There were no clear trends in the total densities of woody plants around watering points, but there were signs of highest densities at the middle or far (communal lands), at the near or far (ranches), and at near only (game reserves). Results of the height class distribution were inconsistent among the land use systems but generally showed no trends around the water points. Therefore, artificial water points cannot be used as one of the bush encroachment detects indicators. The soil quality trends around water-points in the current study showed that livestock and game animals had clear effects on soil parameters. The current study supports the view of non-equilibrium concepts which emphasized periodic and often stochastic events of rainfall, topography and soils as the greater contributors of vegetation changes (Ellis and Swift, 1988).

6.3 Recommendations

It is important to consider the location or distribution and number of artificial watering points within a site (farm) among all land management systems especially communal areas. Livestock watering points need to be planned, designed and utilized to enable sustainable range resource management. In the current study, woody encroachment seems solvable in that most abundant size classes is >0 – 2m, which means that adequate burning to control it is recommended. South African government should urgently intervene by providing machinery to communal farmers to construct new more water points for livestock.

6.4 Further Research

- Further research should consider the nutrition value of grass and woody vegetation found along distance from water points in different land management systems in order to conclude about the potential of land/soil around water points.

- Due to limited technical support and logistical challenges during analysis, soil micro-nutrients were not taken into consideration, therefore, future studies may consider soil macro and micro nutrients along distance from water points in different land management systems.

REFERENCES

Aucamp, A.J. 1976. The role of the browser in the bushveld of the Eastern Cape, *Proceedings of the Annual Congresses of the Grassland Society of Southern Africa* **11(1)**: 135-138.

Bonifica. 1992. Technical Assistance to the Department of Wildlife and National parks: Initial measures for the conservation of Kalahari ecosystem. Project N.6100.026.14.001.

Bot, A. and Benites, J. 2005. The importance of soil organic matter Key to drought-resistant soil and sustained food production. Sales and marketing group Information Division Food and Agriculture Organization of the United Nations Viale delle Terme di Caracalla 00100 Rome, Italy.

Ellis, J.E. and Swift, D.M. 1988. Stability of African pastoral ecosystems: alternate paradigms and implications for development. *Journal of Range Management* **41**: 450–459.

Gandiwa, P.Z., Mabika, C.T., Kupika, O.L., Gandiwa, E., and Murungweni, C. 2013. Vegetation Structure and Composition across Different Land Uses in a Semiarid Savanna of Southern Zimbabwe. Hindawi Publishing Corporation. International Journal of Biodiversity. Volume 2013, Article ID 692564, 5 pages. http://dx.doi.org/10.1155/2013/692564

Nsinamwa M, Moleele NM, Sebego RJ. 2005. Vegetation patterns and nutrients in relation to grazing pressure and soils in the Sandveld and Hardveld communal grazing areas of Botswana. *African Journal of Range and Forage Science* **22**: 17–28.

Smet, M. and Ward, D. 2005. A comparison of the effects of different rangeland management systems on plant species composition, diversity and vegetation structure in a semi-aridsavanna. *African Journal of Range Forage Science* **22**: 59-71.

Smet, M., Ward, D. 2006. Soil quality gradients around water-points under different management systems in a semi-arid savanna, South Africa. *Journal of Arid Environment* **64**: 251-269

Tefera, S. Snyman, H. A. Smit, G. N. 2007. Rangeland dynamics of southern Ethiopia: (2). Assessment of woody vegetation structure in relation to land use and distance from water in semi-arid Borana rangelands. *Journal of Environment Management* **85(2)**: 443-452.

Tefera, S.B., Snyman, H.A., Smit, G.N. 2007a. Rangeland dynamics in Southern Ethiopia: 1 Botanical composition of grasses and soil characteristics in relation to land-use and distance from water in semi-arid Borana rangelands. *Journal of Environmental Management* **85**: 429-442.

Tefera, S., Dlamini, B.J. and Dlamini, A.M. 2010. Changes in soil characteristics and grass layer condition in relation to land management systems in the semi-arid savannas of Swaziland. Journal of Arid Environments **74**: 675–684.

Tefera, S. 2013. Rangeland degradation in semi-arid Swaziland: effects of dip-tanks on herbaceous vegetation and soil properties. *African Journal of Range and Forage Science*. 2013: 1–14

Todd, S. W. 2006. Gradients in vegetation cover, structure and species richness of Nama

Karoo shrublands in relation to distance from livestock watering points. *Journal of Applied Ecology* **43**: 293–304.

APPENDICES

Appendix A: ANOVA results for grass species composition (%) and total dry matter yield (Kg ha¯1) in relation to land management systems.

Dependent Variable: *DiEr*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	13919.2071	6959.6036	14.23	<.0001
Error	285	139403.1833	489.1340		
Corrected Total	287	153322.3904			

Dependent Variable: *ThTr*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	3353.56734	1676.78367	7.33	0.0008
Error	285	65173.19620	228.67788		
Corrected Total	287	68526.76353			

Dependent Variable: *CyDa*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	3388.16842	1694.08421	6.72	0.0014
Error	285	71813.48094	251.97713		

Corrected Total	287	75201.64936			

Dependent Variable: *SpFi*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	2	993.88503	496.94251	7.32	0.0008
Error	285	19348.25479	67.88861		
Corrected Total	287	20342.13982			

Dependent Variable: *ErOb*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	2	3004.02220	1502.01110	8.38	0.0003
Error	285	51110.77433	179.33605		
Corrected Total	287	54114.79653			

Dependent Variable: *ErCa*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	2	4284.10909	2142.05454	14.92	<.0001
Error	285	40918.20557	143.57265		
Corrected Total	287	45202.31466			

Dependent Variable: *ErCh*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2755.74694	1377.87347	13.02	<.0001
Error	285	30170.95856	105.86301		
Corrected Total	287	32926.70550			

Dependent Variable: *SeNe*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	10923.63544	5461.81772	34.84	<.0001
Error	285	44677.64943	156.76368		
Corrected Total	287	55601.28487			

Dependent Variable: *SpAf*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	397.17950	198.58975	3.48	0.0322
Error	285	16279.47702	57.12097		
Corrected Total	287	16676.65652			

Dependent Variable: *CyPl*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	2	2827.95877	1413.97938	22.58	<.0001
Error	285	17845.28758	62.61504		
Corrected Total	287	20673.24635			

Variable Dry Matter

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	123070134.7	2797048.5	4.04	<.0001
Error	243	168208365.9	692215.5		
Corrected Total	287	291278500.6			

Appendix B: ANOVA results for woody vegetation composition and structure in relation to different land management systems and distance gradients from water

Dependent Variable: *Acacia karoo*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	34507195.90	784254.45	3.89	<.0001
Error	243	48980391.90	201565.40		
Corrected Total	287	83487587.79			

Dependent Variable: *Coddia rudis*

	Sum of				
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	2238596.429	50877.192	4.07	<.0001
Error	243	3035703.908	12492.609		
Corrected Total	287	5274300.336			

Dependent Variable: *Maytenus capitata*

	Sum of				
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	884384.869	20099.656	1.80	0.0030
Error	243	2719244.155	11190.305		
Corrected Total	287	3603629.024			

Dependent Variable: *Ehretia rigida*

	Sum of				
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	1268417.232	28827.664	3.93	<.0001
Error	243	1783256.981	7338.506		
Corrected Total	287	3051674.214			

Dependent Variable: *Grewia robusta*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	1466355.199	33326.255	3.83	<.0001
Error	243	2112573.300	8693.717		
Corrected Total	287	3578928.499			

Dependent Variable: *Rhus refracta*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	799667.040	18174.251	3.22	<.0001
Error	243	1373209.439	5651.068		
Corrected Total	287	2172876.478			

Dependent Variable: *Scutia myrtina*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	628746.295	14289.689	2.02	0.0005
Error	243	1721775.680	7085.497		
Corrected Total	287	2350521.975			

Dependent Variable: *Rhus longispina*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	501379.927	11394.998	1.44	0.0462
Error	243	1925794.855	7925.082		
Corrected Total	287	2427174.782			

Dependent Variable: *Aloe ferox*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	1283570.636	29172.060	1.87	0.0016
Error	243	3789403.830	15594.254		
Corrected Total	287	5072974.466			

Dependent Variable: *Maytenus polycantha*

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	44	493723.381	11220.986	1.48	0.0347
Error	243	1843474.382	7586.314		
Corrected Total	287	2337197.763			

Dependent Variable: Total Woody Density

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	0.000	0.000	0.00	1.0000
Error	249	7172916.667	28806.894		
Corrected Total	263	7172916.667			

Dependent Variable: Tree Equivalence (TE)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	44	53129465.3	1207487.8	3.45	<.0001
Error	243	85092239.5	350173.8		
Corrected Total	287	138221704.9			

Appendix C: ANOVA results for soil physical and chemical properties

Dependent Variable: Bulk Density

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	34	5.40157778	0.15886993	0.98	0.5060
Error	109	17.62739722	0.16171924		
Corrected Total	143	23.02897500			

Dependent Variable: Organic matter

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	34	266.066390	7.825482	2.00	0.0010
Error	397	1554.709715	3.916145		
Corrected Total	431	1820.776105			

Dependent Variable: Soil EC

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	34	1348345.558	39657.222	2.07	0.0024
Error	109	2084644.722	19125.181		
Corrected Total	143	3432990.280			

Dependent Variable: Soil pH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	34	8696.05889	255.76644	0.99	0.4895
Error	109	28053.00667	257.36703		
Corrected Total	143	36749.06556			

Dependent Variable: Soil Compaction

		Sum of			
Source	DF	Squares	Mean Square	F Value	Pr > F
Model	34	6223.928611	183.056724	3.67	<.0001
Error	37	1846.570139	49.907301		
Corrected Total	71	8070.498750			