ASSESSMENT OF RANGELAND CONDITION AND EVALUATION OF THE NUTRITIONAL VALUE OF COMMON GRASS AND BROWSE SPECIES AT THE NEUDAMM EXPERIMENTAL FARM, NAMIBIA

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN RANGELAND RESOURCES AND MANAGEMENT

OF

THE UNIVERSITY OF NAMIBIA

FACULTY OF AGRICULTURE AND NATURAL RESOURCES

DEPARTMENT OF ANIMAL SCIENCE

BY

NYAA-LUA KAPU

(201090180)

MARCH 2012

MAIN SUPERVISOR: PROF. ISAAC MAPAURE (UNIVERSITY OF NAMIBAI)

CO-SUPERVISOR: PROF IRVIN MPOFU (UNIVERSITY OF NAMIBIA

Abstract

A case study assessment of rangeland condition and evaluation of the nutritional value of common grass and browse species at the Neudamm experimental farm was done from January to September 2011. The study objectives were to determine the botanical composition of grass and browse species, evaluate the nutritive values of common grass and browse species, determine rangeland condition among three camps under different management practices at the Neudamm experimental farm of the University of Namibia. For botanical composition of grass species, the step point method proposed by Hardy & Walker (1991) was used. Chi-square contingency table was used to analyze herbaceous species composition among the three contrasting camps with alpha at (0.05%), while P>0.0445221 showed a significant different between camps. Neudamm farm is at least 10000hectares in size and represent a typical commercial rangeland farm in Namibia. It was found that grazing camps which had been rested for a period of four years were in a very good state of health than those which had not been grazed annually and continuously. It was found that grazing camp under continuous utilization carried the greater number (28.13%) of decreaser species which are the most palatable grasses with high grazing value than the rested camps (28.07% versus 16.00%) respectively. From the chi-square contingency table (two sided test analysis), there was a significant difference

(X^2=4.51; df= 10, α=0.05) between camps for the functional distribution of species. There was a significant difference ($P<0.05$) between camps for woody plants with the 4-year rested camp (B-7) accounting for a very high density of (2760) of woody plants. From the Pearson Chi-square test, it was statistically proven that woody plants' height class density was <1m. The difference in the distribution of woody plants density per hectare was statistically significant with camp B-7 carrying large proportion for both height class and density for the three (3) height classes. Proliferation potential was higher in B-7 with majority of the trees been *Acacia mellifera, Leucosphorasbenzii, Tarchonanthus camphorates, Catopharactusalexandrii.* Height class <1m was significantly different with a high density (of 68.00%) of all tree count than the <2m and >3m height classes.

The study affirmed that grass and browse species contribute substantially to the availability of feed in livestock production in the Khomas District Highland savanna.

Dedication

I dedicated this thesis to the Almighty God for his guidance in sustaining my life till this time. I also like to dedicate this work to my mother Clare N. Teeman and my grandma Gormah Saywhen and my father Kwellegbo G. S. Kapu for their parental elegance and patience while I was away from home. I would also like to dedicate this thesis to my entire friends in struggled for the year of 2010-2011 for their level of support.

Acknowledgements

I would like to extend special gratitude to my main supervisor Professor Isaac Mapaure and co-supervisor Professor Irvin Mpofu for their invaluable contributions in making this work successful. My sincere acknowledgements also go to my sponsors; the Namibian Government and Research and Publications Office of the University of Namibia for their immense logistical and additional financial assistance for making this research a success. I extend my sincere thanks and appreciation to the University of Namibia-Neudamm farm manager Mr. E. Beukesand the Neudamm security officer John for their countless services offered during the period of this study. I extend special gratitude to Dr. Patrick Graz for his technical resourcefulness towards this research. My gratitude also goes to the Department of Animal Science who facilitated in many ways during the research work. I would humbly like as well to gratify my dynamic President of Liberia who gave me the opportunity to come to Namibia. All in all, I will extend a big appreciation to my family back home for their moral and spiritual support.

Declaration

I, Nyaa-LuaKapu, hereby declare that this study is a true reflection of my own research, and that this work has not been submitted for a degree in any other institution of higher education.

I, Nyaa-LuaKapu, grant the University of Namibia the right to reproduce this thesis in whole or in part, in any manner or format, which the University of Namibia may deem fit, for any person to any institution requiring it for study and research; provided that the University of Namibia shall waive this right if the whole thesis has been or is being published in a manner satisfactory to the University.

……………………………… Date……………………………….

Nyaa-LuaKapu

Acronyms

1. GDP ....Gross Domestic Product
2. LSU ……………Livestock Unit
3. NDTF ………….National Drought Task Force
4. MAWF ……Ministry of Agriculture, Water and Forestry
5. EIM …………..Ecological Index Method
6. AUMs………….Animal Unit per Month(s)
7. Lb………………Pound
8. FAO……………Food and Agriculture Organization
9. UNEP………….United Nations Environmental Program
10. CRD ………….Complete Randomized Design
11. SAS...................Statistical Analysis System
12. HCA..................Hierarchical Cluster Analysis
13. DCA..................Detrended Correspondence Analysis
14. CCA..................Canonical Correspondence Analysis
15. ECI ....Ecological Condition Index

Table of contents

LIST OF TABLES

LIST OF FIGURES

Chapter 1

Introduction

1.1. General background

Rangelands in the Southern Africa regions are largely arid and semi-arid landscapes with limited opportunities for crop cultivation but very suitable for ruminant livestock production. This is due to frequent droughts and low but fluctuating annual rainfall pattern. Most farmers therefore prioritize livestock production.

The term rangeland globally refers to area with arid or semi-arid and dry sub-humid climates, and where topography and soils are unsuitable for food crop farming.

The production systems in these dried regions are mostly (about 70%) managed by rural people, who own and manage multipurpose enterprises in which livestock is an integral part (Winrock, 1992). Hence livestock production contributes to food security through direct production of food (animal products) as well as through non-food functions (Sanon, 1999).

Rangeland is also used for wildlife conservation for which tourists may pay visits to see the species diversity and are also used for trophy hunting which is the focus to income generation for the people of Namibia. Namibia is one of the most sparsely populated Countries in the world on earth. Barnard (1998), found a large portion of arid and semi-arid vegetation types characterized by persistent drought, low and variable rainfall, high evaporation and high temperature. The vegetation types of Namibia ranges from desert type to savanna. The savanna is divided into three main veld types namely the dwarf shrub savanna in the center-south, the various Acacia-based tree, the shrub savanna in the center and eastern part, and the mopane savanna in the north-west (Sweet, 1998a). Rangelands represent valuable national economic resources as well as means of subsistence to the people of Namibia. The northern parts of the country account for 10-12% of the agricultural Gross Domestic Product (GDP) and about 900,000 of the 2.1 million people are supported by communal farms from 150,000 households. Livestock owners in communal areas are mainly subsistent farmers. Commercial livestock production accounts for over 80% of national agricultural GDP with a population of 4,500 farmers on 6,000 large farms that cover 52% of nation's agricultural land.

For the last few decades, there has been a growing concern that majority of the rangelands (both communal and private) in Namibia have extensively deteriorated as a result of inappropriate management practices and due to bush encroachment (Skarpe, 1991). The term bush encroachment can be defined as the increase in density of woody plants with retrogression of herbaceous layer (Roques *et al*., 2001; Francina and Smit, 2006; Wigley, 2006). Some inappropriate management practices of rangeland that has the propensity of changing a healthy rangeland biodiversity would be over grazing resulting from higher carrying capacity on an otherwise productive under size piece of land. Over grazing leads to soil erosion and can hinder the net primary production of grass layer. Many studies have projected soil nutrients and their accessibility to be important factors controlling net primary productivity of rangeland's natural vegetation (Pastor and Post, 1986; Seastedt *et al*., 1991; Du Preez and Snyman, 1993; Snyman, 2002).

Another important factor is the complete abolition of the use of fire as a veld management tool on the rangeland which leads to the increase in fuel load and embraces bush encroachment.

At least, part of the failed efforts to avert the degradation of rangeland biodiversity can be attributed to lack of practical applicable methods of preserving the condition of the rangelands. The concept 'rangeland condition' has been used to describe the 'state of health' of rangelands in terms of its ecological status, resistance to soil erosion and its potential to produce forage for sustained optimum animal production (Trollope *et al*., 1990). The purpose of rangeland condition assessment is to quantify the spatial and temporal changes in vegetation and soil. This is based on a concern for both short and long-term productivity as well as ecological integrity of the rangelands.

Subjective and quantitative techniques have been used in rangeland condition assessments and the choice of the method and factors to be considered depends on the local conditions. In general, in any assessment of a rangeland ecosystem that is composed of different vegetation components, rangeland monitoring must incorporate three levels of assessments. These are the herbaceous layer, the soil, and the tree-shrub layer. In the arid and semi-arid rangeland of Namibia, grass and woody vegetation are more sensitive-indicators of ecosystem change, easier to perceive and to measure than soil.

1.2. Statement of the problem

In many parts of Namibia's rangeland, the severity and magnitude of ecological deterioration is marginally understood. In particular, there have been few in-depth studies directly investigating herbaceous productivity, bush encroachment, and soil characteristics especially in commercial grazing areas like the University of Namibia's Neudamm Campus Experimental farm (De Klerk, 2004). Moreover, there is no adequate information with respect to the nutritive value of grass and browse species particularly describing the nutritional patterns towards the end of the growing seasons. This study therefore, sought to contribute to a complete understanding of the extent to which rangelands have deteriorated and take cognizance of the forage's nutritional value during the winter and spring months. More investigation on the perception of the management practices on rangeland condition was done to ascertain the succession of forage species best suited for livestock production. This study was therefore meant to provide the level of degradation of the ecology of the Neudamm experimental farm as a case study by comparing rested and un-rested grazing camps.

1.3.Objectives

1.3.1. General objective

The general objective of this study was to determine the extent of rangeland degradation and to determine how the improvement of the health condition of rangelands at the Neudamm experimental farm can be effected.

1.3.1.1. Specific objectives

I. To determine the botanical composition of grass species at the Neudamm experimental farm in rested and continuously utilized grazing camps.

II. To determine the density and height class of woody species influence on range condition per hectare at the Neudamm experimental farm grazing camps; rested and un-rested.

III. To assess the status of the physical and chemical properties of the soil at different depth at the Neudamm experimental farm's rested and unrested grazing camps.

IV. To evaluate the nutritive values of grass species and dominant browse species at the Neudamm experimental farm in the rested and unrested grazing camps.

V. To determine species diversity amount grasses in individual plot as well as the three experimental camps at the Neudamm experimental farm.

VI. To ascertain information on rangeland condition among three camps under different resting regimes at the Neudamm experimental farm.

1.4. Hypotheses of the study

1**.** There is no significant difference in species functional type distribution between rested and un-rested grazing camps at Neudamm farm.

2. Species composition is the same for the ecological functional types in the rested and un-rested grazing camps.

3. There is no significant difference in the correlation of height classes and woody plants density per hectare between camps.

4. There is no significant influence of soil nutrient to the composition of herbaceous among camps for productivity level.

5. There is no significant difference in the physical properties of soil across the three (3) contrasting camps at Neudamm.

6. There is no significant variation within herbaceous composition among the three camps.

1.5. Significance of the study

Several studies have identified soil characteristics as determinant factors of changes in the productivity, structure and composition of vegetation. Therefore, a study on these aspects of soil and vegetation properties in a grazing gradient at the Neudamm experimental farm is of paramount importance to predict the rate of ecosystem changed and to explain the impact of disturbance on soil, vegetation and subsequent impact on livestock production.

It is foreseen that this study would generate information to facilitate long-term planning for the provision of adequate forage for livestock on the 10 000 Ha Neudamm farm rangeland.

Chapter 2

Literature Review

2.1. Rangeland management practices in Namibia

Namibia has one of the largest rangelands in Southern Sahara Africa. Its rangeland is being utilized under three systems of tenure-ship: commercial ranching, communal livestock grazing and game reserves.

2.1.1. Communal livestock grazing

Communal rangelands are grasslands which are not privately owned by individuals, but belonged to the entire communities whose members have equal access to free resources. This system is particularly important for rural dwellers and it is the common tenure system found in most parts of Namibia. Communal tenure system accounts for mass production of cattle and small stocks like goat and sheep as well as a diversified proportion of wild life resources. Communal areas comprised about (48%) of the entire farming areas of Namibia and hold roughly 62% of the total cattle population, (72%) of the goats and (17%) of the sheep.

In most communal rangelands in Namibia, livestock are not herded to new pasture during the rainy season which hinders the growth needs of perennial grasses and is generally not part of their management practices. As a result of such management practices, livestock are left to wander around water points in order to re-graze plants that have previously been grazed before they restore their root reserves as well as over resting plants further from the water points. Continuation of this practice over time results in overgrazing which is detrimental to deterioration of rangeland (de Klerk, 1999). Livestock stocking rate in communal areas were reported to be 2-4 times higher than the recommended stocking rate of 8-10ha/LSU (Owen-Smith and Danckwerts, 1997;MAWARD unpublished) based on a long term carrying capacity of 400-500kg livestock mass/ha (Mendelsohn et al., 2002). Communal rangelands have no basic specific recommendations on carrying capacity; governing the movement of livestock as well as the number of animals to be kept over the grazing period.

On communal rangelands in Namibia, the principal form of fodder fed to livestock is cereal crop residues which are acquired during the harvest season and this makes an important contribution to livestock diets in communal farms especially during the dry period. Some communal area's farmers collect and store at least part of their residues to feed to selected animals such as milking cows and draft oxen, but most of the fodder is utilized at the same time (Directorate and Planning, 1999). Products acquired from these communal farms are used to meet the protein requirement (meat, milk) as well as other products such as draught power, and cultivation for their livelihood.The surplus is taken to local markets for income generation due to their limitation of meeting the international market standard.

2.1.2. Commercial ranching

On the other hand however, commercial farms could are owned by private individual(s), government, or organizations. The commercial farming sector is well developed, capital-intensive and export oriented. Production activities vary markedly from the commercial ranching areas in their production systems, objectives and property rights.

In commercial areas livestock production account for 69% of national agricultural output (Directorate of Planning, 1999), and comes from 52% of the farming and or grazing land. The commercial areas are distributed into 6, 337 farms with an average size of 5, 700 ha, owned by about 4,200 individuals and a few agricultural enterprises.

The commercial areas are divided into fenced ranches, further subdivided into a number of paddocks or grazing camps, through which some form of rotational grazing is normally practiced. Compared to the communal areas; stocking rates tend to be more conservative but fire has generally been excluded, cutting for fuel or building is minimized, there are fewer browsing animals and there is less mobility (pastoralism) in response to rainfall spatial and temporal variation. During drought years, commercial farms owners do purchase feed and supplements either from neighboring countries or from feed companies to meet the nutritional requirements of their livestock through the trying period(NDTF, 1997b).

2.1.3. Game ranching

Southern Africa regions possessed a rich and diverse wildlife resource, with many unique and interesting mammals, birds, reptiles and amphibians, providing a wide range of products, including tourism opportunities, meat, hides, curios, recreation and trophy hunting.

In response, there has been a remarkable increased in game farming and wildlife tourism in the commercial areas, in recognition of the difficulties and consequences of farming with mono-specific (grazer) domestic stock. Games provide about 4,400 tones of meat for rural and some urban dwellers in Namibia. Rangeland management practices vary in grazing capacity, stocking rate and the restoration period for rejuvenation.

2.2. Rangeland (veld) condition

The condition of a rangeland reflects the health of herbaceous vegetation within a savanna ecological environment. Species composition of grasses is a clear indicator of a rangeland ecosystem due to its diversities and significance to herbivore. The acceptability of these species depends on the grazing value and the palatability to the grazing herbivore and also due to phenological differences (e.g. rhizomatous, stoloniferous or tall tufted grasses) (Snyman, 1998; Solomon, 2003). In any grassland ecosystem, the most useful plants species are referred to as key species that can be used to measure the qualitative composition of a rangeland condition. The condition of a rangeland can be buffered by taking into account the influence of the soil physical and chemical properties which enhances the growth ability of herbaceous species. Seastedt *et al.* (1991) and Snyman (2002) suggest that, the physical and the chemical properties of a soil in a rangeland ecosystem serve as a determinant of changes in the productivity, structure, composition of vegetation and the rate of ecosystem process (Schimet *et al*., 1991).

The Ecological Index Method (EIM) described by Vorster (1982) as giving by Van Rooyen *et al.* (1996) was used for the manipulation of the proportional species composition data in a rangeland. This is a reliable method for the determination of veld condition assessment and can well be used for rangeland condition's study. According to this method, the veld condition of a specific site is compared to that of a reference or benchmark site. The reason for differences in the ecological and grazing value of different grass species is that, the Ecological Index Method makes use of the grass species composition to obtain veldt condition. Normally, there is a correlation between the ecological status of different grass species and their grazing value proposed by Van Rooyen *et al*. (1996). In the process of determining the ecological status of grass species composition, evaluation is done in order to classify grass species on the basis of their reactions to grazing. According to Van Rooyen *et al.* (1996), the following ecological status classes (ecological categories) are generally used based on the following criteria:

- Decreaser: A species composition of grass which is dominant in good veld which is well managed, but could be decreased over time when inappropriate management practice gears in (over grazing or under utilization of veld).
- Increaser I: These are grass species which progress when veldt is selectively utilized or under-utilized.
- Increaser II: Grass species that are lightly overgrazed and are found in high population in a poor veldt condition as a result of relative over utilization or moderate grazing intensity (moderate overgrazing).
- Increaser III: A grass species which is dominant in poor veld and increases as a result of heavy overgrazing.
- Invader: A grass species which are foreign to the plant community or increase aggressively.

The ecological status of many species is constant over a wide range, exceptions do however, exist. Some of the widely distributed grasses may act as ecotypes because of genetic variation. Different ecotypes may react differently to grazing in the areas where they occurred and can thus be classified into different ecological status classes in other environment. The ecological status of a species can also be influenced by differences in environmental and habitat conditions. It is therefore, necessary for rangeland managers to determine to which ecological category a species belong in order to determine the veld condition on a ranch. In order to determine the veld condition of a sample of veld, a grazing value is allocated to each of the ecological categories. The following relative ecological index values are used:

- Decreasers 10
- Increasers I 7
- Increasers II 4
- Increasers III 1

2.3. Grazing capacity

Ideally, grazing capacity and stocking rate are synonymously used (Booysen, 1967), where grazing capacity is essentially the theoretical consideration and stocking rate the practical implementation. Both are for convenience, and also for obvious and real practical reasons, either expressed in terms of hectares/stock-unit/year or per grazing season. Danckerts (1982) cautioned that for mathematical considerations, grazing capacity should be expressed in stock-units/hectare because there is a linear relationship between the number of animals and the area of land occupied.

Grazing capacity was defined by Booysen (1967) as describing the productivity of rangeland vegetation in terms of the area of land required to maintain a specific number of animals over an extended period without deterioration of vegetation or soil condition under a healthy management condition of a rangeland or could be the number of hectares required in the long term to sustain a stock-unit at maximum production under normal fluctuating climatic conditions, without any deterioration of the resource.

Booysen (1967) postulated that for comparative purposes it is desirable that the area be expressed in terms of the customary unit of land area measurement for the country, that the specific number of animals reflects a single animal unit and that the time be stated as the length of the period and that grazing is useable in each year.

Booysen's (1967) definition does not imply, but is clearly aimed at, definition of a situation which can be maintained over "an extended period". Danckwerts (1982a) suggested a revised definition on the rather tenuous grounds that grazing capacity may change due to "fluctuations in rainfall or changes in veldt condition". His revised definition thus added nothing new other than to limit grazing capacity to grazing season and make provision for change outside of one season. This seems to confound and defeat the object of the original definition and in any case Booysen does make provision for grazing season as well. It is expressed in ha/su/year." Grazing capacity may well be a theoretical abstraction (Tidmarsh, 1951); the overall stocking rate (and manipulation thereof) which achieves the goals of sustained maximum production in any production system is the correct grazing capacity within that system. Grazing capacity describes the average number of animals that can be accommodated on a pasture land for a season without harming it. Expressed in animal unite per month(s) AUMs, it is a measure of a pasture and its ability to produce enough forage to meet the requirements of grazing animals. Carrying capacity can be determined by experience gained over the years, or by calculating long-term forage yields for the pasture, if possible. This information is used to determine how heavily a pasture can be stocked. For example, a pasture with a carrying capacity of 120 AUMs can support 30 animal units for four months (120 AUMs divided by 4 month). If larger or smaller animals are placed on the pasture, the carrying capacity does not change, but the stocking rate does. For example, grazing 30 - 1,500 lb. cows on this same property for four months would result in over-grazing. Cows weighing 1,500 lb. require approximately 50 per cent more forage than cows weighing 1,000 lb. Therefore, the stocking rate for 1,500 lb. cows would be 50 per cent lower or about 20 animals, (Retrieved May 15, 2011 from the World Wide Web, 5/14/2007 10:35:28 AM http://agr.gc.ca/pfra/land/fft1.htm (2 of 4).

2.4. Importance of browse species in ranch management

Browse refers to leaves and young edible branches from shrubs and trees available to ruminants as feed. In a broader spectrum it could include also flowers and fruits or pods that are well utilized for feeding purposes. The conception of browse is a complex issue which was discussed by Le Houerou (1980), stating that, depending on plant species, animal species forage availability and accessibility and the level of nutrient obtained by the animals. Wicken (1980) estimated that the flora of tropical Africa contains as much as 7000 species of trees and shrubs of which at least 75% are browsed to a greater or lesser extent, and probably about 50% are useful to the livelihood of human environments. Apart from being browsed, woody plants have always played a significant role in human livelihood in Southern Sahara Africa as demonstrated by their multiple usages. With regard to crop production, farmers in semi-arid region in West Africa have traditionally spared desirable species when establishing their fields by clearing natural vegetation. Such species like the *Acacia albida*are valuable due to its ability to integrate soil fertility through nitrogen fixation, and also because of the reverse vegetation cycle of this tree, that produces green leaves in the dry season for feeding animals, and the animals in turn spread manure on the field. Due to the density of browse plants are essential in Namibia, *Acacia mellifera* which is commonly known as blackthorn is one of the dominant fodder trees in the Kalahari sand region that serves as an important fodder with high percent of raw protein and is thus often ground to feed game and livestock. The tree produces an edible gum which is obtained from damaged branches, the branches often being deliberately damaged for this purpose. In Botswana its roots are believed to be used in the curing of stomach pain.

In the rainy season the species lose their leaves, resulting in no shading effects on the crop. Other species maintained in the croplands have different socio-economical importance (edible leaves or fruits, ethno-medicinal use or shade) and reduce evaporation from the fields. Overall the multiple uses of woody plants include soil maintenance and protection against erosion and dune stabilization (as windbreaks), source of energy (fire wood), construction material and with their shade reduced water loss from the soil and lower temperature. Some woody plants serve the purpose for income generation through the sale of leaves, fruits, wood, and ethno-medicinal and veterinary uses as well. Browse species influence the herbaceous cover of some grass species in rangeland area by improving the flora diversity and mineral content (Akpo *et al.*, 2003).

2.4.1. Knowledge on the use of indigenous browse species in rangeland

Rural inhabitance in arid regions in the world generally recognize trees and shrubs which are well appreciated by ruminants for their nutritive importance (Thapa *et al.*, 1997; Briggs *et al.*, 1999; Thorne *et al.*, 1999; Komwihangilo *et al.*, 2001) especially during the period of droughts . The importance of browse during periods of drought has been acknowledged and attracted interest from numerous researchers. For the improvement of forage production, the screening of browse plants and evaluation of biomass production has concentrated on improved species such as *Leucaena leucocephala*and *Gliricidia sepium*, for which planting material and information are available from international sources. Hence, some authors have recently focused on screening indigenous fodder trees and shrubs by involving the role of farmers in choosing promising species. Indigenous browse species that are well adapted to the local environment are well known by farmers and the planting material can easily be collected in the entire microcosm. The methods have consisted of interviews with informants on the diversity of browse species, knowledge on level of palatability to livestock (Roothaert & Frankel, 2001), the ranking of browse quality coupled with chemical analysis (Bayer, 1990) and the preference of selected animals (Mtengeti & Mhelela, 2006). It appears that local farmers can generate richer data, as the area under consideration will not be limited to direct observation in paddocks as in many studies. The ranking of fodder quality revealed knowledge of its correlation to the chemical composition. The knowledge of palatability in different animal species was obtained by observing feeding preference of fodder species by browsing animal in the ranch. Hence, farmers' preference of browse species is also related to the availability, palatability and drought resistance. According to Niamir (1990) browse species have correlation to productivity by stimulating milk and meat production, the toxicity, saltiness and medicinal value, the ability to indicate the agricultural potential of soil and the prominent characteristics such as prolific fruiters and fast growth. The studies stressed the advantages of incorporating browse species into livestock nutrition in both communal and commercial ranching in Southern Sahara Africa and taking into consideration of local knowledge of their insight into livestock production.

2.5. The problem of rangeland degradation

Rangeland degradation is defined as the retrogression of vegetative cover leading to surface layers exposure to wind and soil erosion by washing away the organic compositions that give vigor to plants development (Solomon, 2003). Degradation of rangeland can also reflect the natural disturbance of grassland vegetation by woody plants. The vegetation indicators usually considered as useful detectors of rangeland degradation are: low grass cover, predominance grasses of low palatability, and change from species composition where perennials predominate to one dominated by annuals - particularly forbs, and increase in woody vegetation density known as bush encroachment. Other indicators of decreased rangeland condition are: decreased in soil water availability, and livestock condition which may however lag behind the deterioration in vegetation (Wilson *et al*., 1984; Snyman, 1999). One of the problems of the occurrence of degradation would be the availability of permanent drinking station of cattle which exposes the grasses to continuous grazing pressure to which they are not adapted. Thus, the establishment of permanent water point to improve rangeland actually backfires and exacerbates deterioration of the grass resource base (Glantz, 1976; Picardi and Siefert, 1976).

Rangeland degradation has been observed on every continent where arid and semi-arid savannas occur (Archer, 1995). Because they are usually too dried to support most crops land and rangelands and are therefore predominantly used for cattle grazing.

Another factor that can be linked to rangeland degradation in Africa could be the processes resulting from both human activities and climatic variability (United Nation Environmental Program, 2008). An estimated 65% of Africa's agricultural land is degraded due to erosion and/or chemical and physical damage of the soil. Thirty-one per cent of the continent's pasture lands and 19% of its forests and woodlands also are classified as degraded (UNEP, 2008; FAO, 2005). Overgrazing has long been considered the primary cause of degradation in Africa but it is now thought that rainfall variability and long-term drought are more important determinants for rangeland degradation. In Sub-Saharan Africa, land degradation is especially widespread affecting (20-50%) of the land and some 200 million people (Snel and Bot, 2003). Furthermore, Snel and Bot (2003) projected that land degradation is also widespread and severe in Asia and Latin America as well as in other regions of the globe. In Latin America and the Caribbean, land degradation affects 16% of their productive land areas. The impact is more severe in Meso-America (reaching 26% of the total, or 63 million hectares) than in South America (where it affects 14% of the total or almost 250 million hectares).

2.5.1 Causes of rangeland degradation

The driving factor behind vegetation dynamics and deterioration of rangelands (grasslands and savannas) still remains a subject of controversy. The most important driving factors of controversy can be summarized as anthropogenic, climate and soil. In southern Africa, the view of many scientists is that the shift in vegetation is associated with anthropogenic activities like establishment of new settlement, collection of wood for house whole use, chipping of timber for construction purposes, as well as inappropriate cattle densities (Skarpe, 1986; Ringrose *et al.*, 1996). Therefore, overgrazing would be well thought-out as the most important cause of rangeland degradation. Rangeland faces crisis of degradation most often when stocking rate exceeds the carrying capacity at the detriment of palatable perennial grasses declining to an extreme level causing them been replaced by undesirable less palatable grasses, annual species (weed and exotic plants) and disrupt the population process of key palatable species. The continuity of over grazing has direct effect on the soil causing the exposure of surface layer leading to soil erosion. Besides, overgrazed rangelands with low plant cover have reduced soil nitrogen and organic matter levels. In the soil, the nitrogen and organic matter are the stimulants for plant emergence and due to any external or internal reason for negating their functionalities; the result directly affects the plant component. High cattle densities and the resultant overgrazing are often associated in this region with communal rangelands, where uncontrolled management of grazing lands prevails. Furthermore, the majority of the users of communal rangelands streamline their contemplation for the survival of their livestock on the limited resources instead of managing the rangeland to ensure the longevity in grazing gradient (Smet and Ward, 2005). On the contrary view of overgrazing, some researchers in southern Africa, however, have argued that overstocking is not the primary driving factor behind rangeland degradation. Climate and soil characteristics are considered the primary determinants of species composition and structure of vegetation communities in semi-arid and arid areas (O'Connor, 1985; Scholes and Walker, 1993). More emphatically, a characteristically marked year-to-year variability of rainfall has been identified as a primary determinant of compositional change in southern Africa savannas (O'Connor, 1985). This hypothesis suggests that grazing is inconsequential and that the community and system dynamics are mainly a function of rainfall variability, yet the current rationale for grazing management in this region is based on the premise of grazing as the main agent of compositional change.

Other external factors such as development of dip tanks and water sources, land alienation through privatization, industrialization and expansion of cultivation, have been most commonly cited as causes of deterioration of rangeland in Africa (Coppock 1994).

2.5.2. Overstocking relationship with degradation

The carrying capacity is the concept that has been used attempting to define the stocking rate in which the grazing pressure is supposed to be sustainable in avoiding overgrazing (Dikman, 1998). The basic principle is that each ecosystem has a potential to produce a certain amount of forage, and this amount defines the stocking rate which could be sustained. It has been used by policy makers aiming to prevent the overgrazing in communal rangelands.

As stocking rate is increased, individual animal performance decreases, while production per unit-area increases to some maximum and then declines as a result of concurrent process controlling plant production and utilization by the grazing animal. Increase in grazing intensity decreases plant solar energy capture because of the negative impact on leaf area index. As the leaf area index is drastically reduced, and then the surface area of the soil will be exposed leaving the land with no alternative but rather being susceptible to degradation. The harvest efficiency is increased with increasing grazing intensity because the forage intake per unit area is increased. Conversely, with increasing the number of animals, the competition for forage decreases intake of the individual animal which moderates the digestion efficiency. From the nature of these relationships the so-called fundamental ecological dilemma encountered in grazing systems emerges (Briske & Heitschmidt, 1991), where the same stocking rate cannot optimize simultaneously the individual animal performance and production per unit area. Forage plants need leaves to capture solar radiation, and animals need the same leaves to be fed and converted into bodily functionalities.

The consequence of these competitive processes is that proper stocking rates depends on production goals and when prioritizes individual animal performance or the stock production per unit area. According to Conner (1991), because of temporal and spatial variation in quantity and quality of forage produced in grasslands, as well as different economic goals, there is not a single optimal stocking rate to maximize production. As a result of uncontrollable factors, desirable stocking rates vary widely with sites, seasons, and years within and among geographical regions.

Moreover, as stocking rate is increased beyond the carrying capacity level, profit levels begin to decline because of production costs, and over grazing gears in which generally increase at somewhat faster rate than the rate of increase in gross returns (Conner, 1991). Thus, as stocking rate is increased beyond a moderate level, the potential of the pasture decrease due to grazing intensity causing degradation. Consequently, stocking rate is limited to support production-oriented policies.

2.5.3. Bush encroachment

Chronic, heavy livestock grazing and concomitant re-suppression have caused the gradual replacement of palatable grass species by less palatable trees and woody shrubs in a rangeland degradation process called bush encroachment in Southern Sahara Africa.

The productivity and longevity of economic viability as well as the ecological integrity of most savannas in Africa can be undermined by increasingly dense thickets of woody vegetation. Increased in density of woody plants has been documented from many semi-arid rangelands in southern Africa (Roques*et al*., 2001; Francina and Smith, 2006; Wigley, 2006) and can alter soil moisture and micro climate (Richter *et al*., 2001; Roques *et al*., 2001). With the suppression of fire and ignorance of native browsers, by grazing policymakers and cattle farmers alike have not appreciated their ecological role played in preventing bush encroachment. Unpredictable droughts are common in South Africa but have deflected too much blame for bush encroachment away from grazing mismanagement. Bush encroachment is widespread on both black and white farms, although the contributing socioeconomic, cultural, and political forces differ. In the process of bush encroachment, highly less palatable trees and shrubs evade rangelands at the expense of palatable grasses reduction or extinction.

Other factors associated with bush encroachment are Climate change and the increasing atmospheric carbon dioxide concentration that have been suggested by other scientists as causes for bush encroachment, but on the contrary, much stronger evidence implicates live stock grazing as the primary cause of bush encroachment (Archer, 1995). Bush encroachment decreases grazing capacity (Richter, 1990), increases transpiration (thus lowering the soil moisture available for grass growth) (Donaldson, 1967), and decreases weaner calf production all of which lead to economic hardship for cattle farmers.

2.5.4. Soil degradation

Soil degradation occurs when the soil chemical or physical conditions have been negatively altered. Examples of soil degradation include acidification, salinization, organic matter depletion, compaction, nutrient depletion, structural deterioration, loss of topsoil, gully erosion, chemical contamination. In Somaliland, the most common soil degradation types identified by experts are loss of topsoil, nutrient depletion, and gully erosion (LADA 2005). Soil degradation occurs in semi-arid rangeland when herbaceous standing crop is insufficient to prevent surface run-off of rainwater, proposed by van de Koppel (*et al*., 1997). Due to this reason the proportion of rainfall that infiltrates into the soil decreases. The process of runoff water on the surface of the earth accelerates soil erosion and flooding. And due to the lacked of vegetative cover of rangeland, the soil eventually losses its moisture content which adversely affect the production of herbage.

Vegetative cover serves as a protective shield for checking soil erosion by protecting the physical binding of soil as well as moisture retention at the surface layer (van de Koppel *et al*., 1997).

Chapter 3

Methodology

3.1. Description of the study area

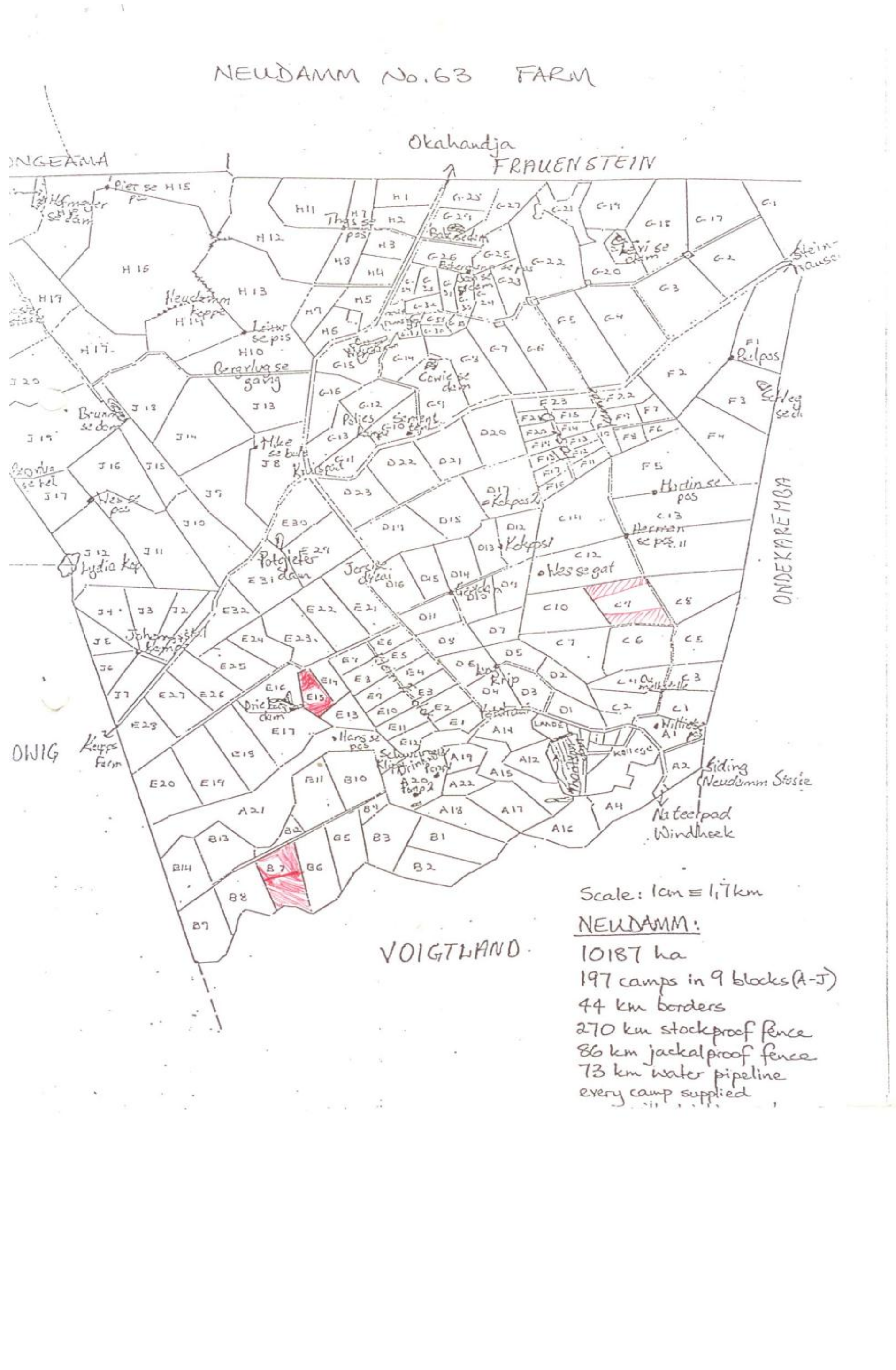
This study was conducted at the University of Namibia’s Neudamm Campus Experimental farm in three camps precisely (B-7, C-9 and E-15). This farm is situated in the Khomas region 27km east of Windhoek (latitude 22º27'02″ S, longitude 17º21'38″ E and altitude 1856 m).

This farm occupies 10,187hactares of rangeland used for cattle, goat, and sheep grazing as well as piggery and poultry. Neudamm’s farm has been used for experimental purposes over many decades by livestock scientists and it is divided into ten (9) blocks from A-J and subdivided into smaller paddocks or grazing camps.

The farm has savanna biome vegetation and its annual rainfall ranges from 300 to 400mm and much of it fall during the month of January to April (Mendelsohn *at el*, 2002).

The farm soils have a clay content of less than (5%), and thus have a very low water holding capacity. The map below shows the Neudamm’s farm and its sub-division in grazing camps.

Fig 1: Neudamm Farm map.



3.2. Research experimental design

The experimental design used in this study was Complete Randomized Design (CRD) for homogeneous ecology. A two-way Analysis of Variance (ANOVA) was used for soil and vegetation nutrients analysis by using the Statistical Analysis System (SAS). The Hierarchical Cluster Analysis (HCA) was used in line with the Average Linkage Between Groups method which was performed on a plots-by-species matrix consisting of 30 plots and 31 species of grass, using presence and absence data. Detrended Correspondence Analysis (DCA), which is a gradient analysis (ordination) technique, was performed on a presence and absence matrix of herbaceous species, to reveal relations among the various plant associations. And lastly, Canonical Correspondence Analysis (CCA) was used to incorporate the correlation and progression between herbaceous and environmental data (Kent and Coker, 2003).

3.3. Population and sampling

Representation of the experimental population was acquired for the entire Neudamm's experimental farm grazing camps. A total of three (3) contrasting camps under different management practices were sampled by using random numbers. In each Camp (E-15, B-7 & C-9) sampled, belt transects up to 1 km north, south, east and west were established and divided into at least six experimental plots from north to south while along the transect from east to west was divided into four plots. Each of the experimental plot was measured 15m x 10m along these transects for data collection of grass and browse species.

3.4. Site selection and data collection

3.4.1. Botanical composition of grass species and dry matter production

Camp E-15 which is currently under grazing by small stock specifically Afrikaner stud breed, Karakul sheep, Damara sheep, Dorper sheep and occupy a total area of 21hacteres. While camp B-7 has been rested for the period of four years without grazing and occupies about 48hactares of grazing land. For camp C-9, it has been reserved during two years period without grazing even though it was grazed before by dairy cattle. This camp in the past was used for grazing dairy cows and it occupies 60hactare of land as well. Botanical composition of grass species from these contrasting camps were obtained from February to May 2011. A belt transect was measured up to 1km in each of the contrasting camps. Along the transect line, six experimental plots measured 15 x 10msquare from north to south and four from the east to west with the distance interval of 20m between plots and 30m away from the centre of the camp to the nearest plot.

In both focal grazing areas, grass species compositions were determined from each of the15 x 10m^2 plots using the Step Point method (Mentis, 1981). The nearest plant, basal strikes and bare patches were recorded from 150m point observations per plot (Hardy & Walker, 1991). In every plot, distance of the nearest plant further than 10 cm from the marked step point, was recorded as "bare ground". Observations of points were spaced by (±) 1m intervals for row and inter row and also record was made available for the length of the plot in straight parallel lines including the 1m distance among the point observation.

Conditions of Veld for these three camps were determined from the composition of grass species by using the Ecological Condition Index (ECI) (Vorster, 1982). The ecological condition percentages were obtained by multiplying the relative index value for each ecological functional group (Decreaser, Increaser I, Increaser II, and Increaser III) by their frequencies (total observed value). The classes (poor, moderate, and good) were analyzed using the condition scores of the three contrasting camps combined with the long term precipitation of the studied areas.

The rainfall reports at Neudamm experimental farm were obtained from the meteorological office of Windhoek (2011), (2008-2010 rainfall patterns).

Grasses were placed in categories of ecological groups ranging from Decreaser, Increaser I, Increaser II and Increaser III. Each of this ecological group was given a relative index value for every group, namely, Decreaser =10; Increaser I=7; Increaser II = 4 and Increaser III = 1. The percent composition of grasses in each class was obtained by multiplying its relative index value by 100 and the amount was accumulated to give the condition index, and was compared to three ranges; poor (0-221.5); moderate (221.5- 393.6); and good (393.6-715.1) used to determine the veld condition score (health or grade).

Estimates of proportional species composition were made by using the step-point method (Mentis, 1981). Species composition and distribution of ecological functional types were analyzed with the aid of the two sided Chi-square contingency table. Two cross line-transects were delineated in the already identified agro-ecological management units. Point observations, identifying the grass species were made at every first (1m) step along these transect by randomly placing a rod down at that point. The data at each sample plot were recorded on herbaceous survey sheets. At each sample plot it was necessary to determine a cut-off distance, in accordance with Mentis's (1981) recommendation. The cut-off distance, was taken as the distance (radius) around the point of the rod (used in 150m^2 point survey per plot) in which a grass species was rooted to be recorded. Formally, the cut-off distance can be defined as that distance in which 95 percent of the time a grass species can be recorded. The cut-off distance was determined by measuring the nearest distance (from point of the rod to the roots of the nearest rooted grass) to the first 15 grass species in the first line transect at each of the sample plots.

3.4.2. Nutrient analysis of grass species

From each of the thirty (30) experimental plots, three quadrates (0.5m x 0.5m) samples were randomly collected for determination of botanical composition as well as nutritional analysis. But due to high quantity of samples for analysis, samples number which is evenly devisable by three (3) were removed.

Samples acquired for nutrient analysis were air dried after which they were milled to pass through a1mm sieve and kept in air-tight plastic containers and sent to the Ministry of Agriculture laboratory for chemical analysis using *in vitro* fermentation in the month of July 2011. Grass tissues were analyzed for percent dried matter (%DM), moisture, ash and crude fibre (CF), using the procedures adapted from the Association of Official Analytical Chemists International (1995). Neutral detergent fibre (NDF) was analyzed by the use of a method modified by Robertson and Van Soest (1981). Phosphorus (P) was determined by using the modified method of Cavell, A.J. (1955) known as colorimetry, Magnesium (Mg), Calcium (Ca), this was obtained from the Oxalate method streamlined by the Association of Official Analytical Chemists International (1995)16th edition. The level of Potassium (K) was determined by the use of Analytical methods of Flame Photometry adapted by Poluektov, N.S. (1973). For the analysis of Iron (Fe), Copper (Cu) and Zinc (Zn), the method of atomic absorption flame spectroscopy was adapted and modified by Association of Official Analytical Chemists, (1990).

3.5. Woody plant data collection

3.5.1. Density of woody plant

Data on woody plants were recorded in the entire 15m x 10m (150meter square) plots of the three camps. All rooted live plants were counted in each plot for the estimation of plant density per unit area converted into hectare with the exception of non-woody plants. Some common woody plants recorded during data collection include: *Acacia erioloba, A. hebeclada, A. karoo, A. mellifera, Blumea galpinii, Catophrqactus alexandrii, Eriocephlus luedretziannus, Leucosphoras benzii*, *Lycium bosciifolium*, *Lycium eenii*, *Phaeoptilum* etc.

Plants data were then standardized to total tree count per camp and one (1) Tree = 1 shrub/tree and vice versa. The data of woody plants were analyzed by using the Pearson Chi-square test.

Height class of woody plants were acquired by using a calibrated aluminumpole from 1to 4m measuring the length of every tree found in each of the experimental plot (<1, >1.1-2, >2.1-3, &>3) Smit, Swart, (1994). Height of all woody plants above 3m was marked as >3m and above.

Each shrub and sapling in the 10x15 m^2 plots was identified as tree and their heights were measured in the same way as that of the trees. Account was not taken on non-woody plants.

3.5.2. Soil sample analysis

A total of twenty soil samples were obtained randomly in each of the management unit and at each sampling sites to a depth of 0-100mm topsoil and 100-200mm subsoil with an auger. The soil samples from each sub-habitat were bulked for each depth thoroughly mixed and a composite sample placed in a plastic bag and taken for analysis. The samples were air-dried then sieved to pass through a 2-mm sieve. The analyses included pH (H_2O), electrical conductivity (ECs), percentage organic carbon (OC), texture, available phosphorous (P) and available potassium (K). For determining soil pH, the procedure of Hendershot *et al*. (1993) was used by supernatant of a mixture of soil and de-ionized water, whereas for determining Electrical Conductivity, soil suspension from identically prepared mixture was used (Bower and Wilcox, 1965). Percentage OC was determined by the wet oxidation method of Walkley and Black (1934); available P was analyzed by the method of Shoenau and Karamanos (1993). Available K was determined by the Morghan extracting solution.Soil particle size was analyzed for percent clay, silt, and sand by the method of Pipette, Miller and Miller, (1987).

And statistically, the SAS package was used to determine the level of soil influence to plants growth

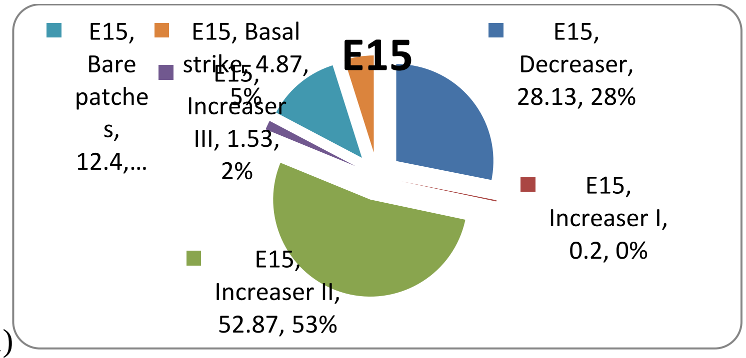
Chapter 4

Results

4.1. Ecological condition and botanical diversity among the three management units

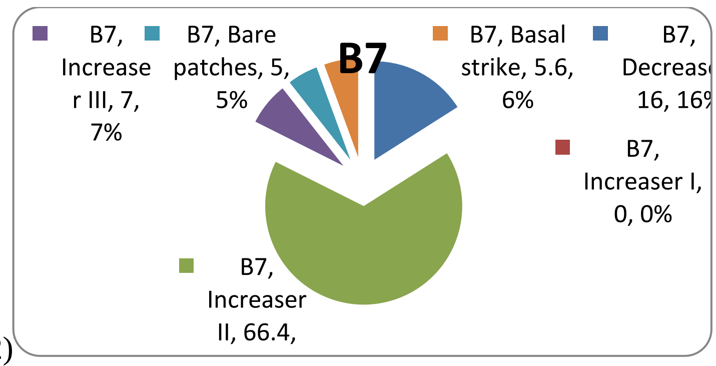
Below, Figures 2, 3, and 4 represent the ranch condition of the three experimental camps as graded for their condition by the use of step point method. Each of the figures below is a representation of a camp with the various proportions for functional type's distribution. The percent composition of Ecological functional types in each class was obtained by multiplying its relative index value by 100 and amount was accumulated to give the condition index, and was compared to three ranges; poor (0-221.5); moderate (221.5- 393.6); and good (393.6-715.1) used to determine the veld condition score (health or grade).

(1)



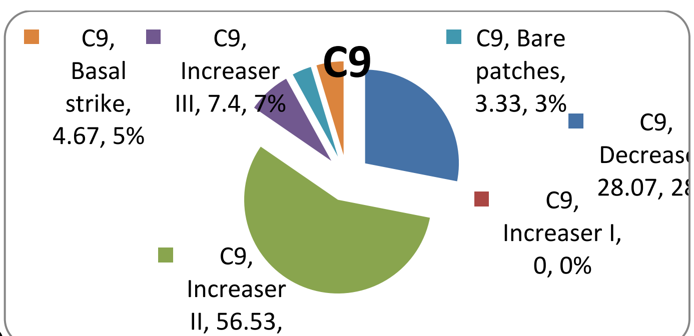
Veldt condition score=599.19

(2)



Veldt condition score= 483.89

(3)



Veldt condition score= 653.04

Figure 2, 3, and 4: Comparison of proportions of various ecological functional types (grasses, bare patches and basal strikes) in (a) Camps E15 (b) B7 and (c) C9 at the Neudamm's experimental Farm.

Table1: shows the evaluation scale using the annual rainfall data to determining veld condition score at Neudamm's Experimental farm. These results range from poor, moderate, and good by using the short term rainfall patterns as a benchmark for determining grazing capacity due to the health of ranch.

Veld condition index	0-221.5	221.5-393.6	393.6-715.1
Veldt condition class	Poor	Moderate	Good

Table1: Veld evaluation scale showing the annual rainfall patterns for the past three (3) years used as a benchmark to obtain grazing capacity over a minimum period of time.

This study indicated that by assessing the veld condition of camps E15, B7, and C9 using the ecological functional index had shown that utilization levels differed significantly ($P<0.05$) among camps. E15 showed a higher level of Decreaser (28.13%) which is the most productive grass species followed by Camp C9 (28.07%) which was slightly lower than the former; but shows a significantly ($P<0.05$) lower level in camp B7 (16.00%) veld condition score. Increaser I in E15 differed significantly ($p<0.05$) among the other management units that showed (0.00%) for species occurrence. It was also proven that among the three utilization levels that Increaser II species account for about (66.40%) in campB7, followed by campC9 with (56.53%) and campE15 with about (52.87%). The results showed a significantly ($P < 0.05$) different level of utilization under different management conditions. Increaser III showed no difference in significance between camp B7 (7.00%) and C9 (7.40%) but differed significantly for camp E15 (1.53%). Differences in bare patches were significant ($P<0.05$) in E15 at (12.40%), while B7's level was (5.00%) and then C9 even lower at (3.33%). Basal strike showed no significant difference between camps.

For variation of veld condition score, the calculations for the three contrasting camps states that C9 condition score (653.04) was however greater than campE15 and B7 nevertheless, C9 condition score was compared with the short term rainfall pattern (2008-2010) in the range of (393.6-715.1) meaning that C9 was in a good veldt condition. The condition score for camp E15 was (599.19) and thus corresponded well to the rainfall pattern of the Neudamm's farm which showed a good result as well. Camp B7 veld condition score (483.89%) was poorer than the other two camps showing retrogression in the productivity (from good to moderate).

4.1.2. Functional distribution and composition of herbaceous species

Table1.2. Shows the actual counts of the ecological functional type occurrence across the three contrasting camps shown from the field assessment using the step-point method.

Status	**E15**	**B7**	**C9**
Decreaser	422	240	421
Increaser I	3	0	0
Increaser II	793	996	848
Increeaser III	23	105	111
Bare patch	186	75	50
Basal strike	73	84	70

Table1.2: Actual observed values from survey in the field

Table1.3. shows the chi-square expected frequency which assumed that the three camps had a homogenous composition of grass species though there is a changed within the expected variables compare to the observed count.

Status	**E15**	**B7**	**C9**
Decreaser	361	361	361
Increaser I	1	1	1.06
Increeaser II	879	879	879
Increaser III	79.67	79.67	79.67
Bare patch	103.67	103.67	103.67
Basal strike	75.67	75.67	75.67

Table1.3: Expected chi-square values

Finally, table 1.4 shows the distribution of each plant functional type between camps and it is reflected by the two sided chi-square contingency table. Table 1.4 below shows the chi-square frequency of ecological functional type's distribution in each of the contrasting Camps

Status	E15	B7	C9
Decreaser	10.31	40.56	9.97
Increaser I	4	1	1
Increeaser II	8.41	15.57	1.09
Increaser III	40.31	8.06	12.32
Bare patch	65.39	7.93	27.78
Basal strike	0.09	0.92	0.42

Table 1.4: Frequency of chi-square

The null hypothesis which states that there is no significant difference in the distribution of species functional type between camps was rejected (α=0.05) in view of the very high chi-square calculated value (X^2cal=255.14; df=10; $P<0.001$).

Comparison of the observed value of step-point (table 1.3) for Decreaser species (422) for campE15 is significantly higher ($P<0.050$) than the chi-square expected value (361) and showed a very small chi-square frequency (10.31) in table1.5. In campB7, the observed value (240) is significantly smaller than the X^2-expected

(361) therefore projecting a chi-square frequency (40.56) much higher than E15 and smaller than the observed value of B7. C9 observed value (421) for Decreaser species differed within the chi-square expected value (361) and show a low chi-square frequency as well. But looking at the repetition, table 1.4, shows that the three camps are not significantly different in species composition. Increaser I (Table 1.2, column 3, row 2) shows an observed value significantly greater than the chi-square expected (1) and shows no difference in the frequency (Table 1.3). But camp B7 and C9 have an observed value of zero (0) with the chi-square expect and frequency reflecting the value of one (1) representing B7 and C9. There is a significantly difference within the observed values and show no difference for the chi-square expected and frequencies value for both camp B7 and C9 respectively. The observed value (793) for Increaser II in campE15 is significantly lower ($p<0.05$) than the chi-square expected value (879) and followed by a very low frequency value (8.41) of chi-square. B7 reflects a different in the observed value (996) of Increaser II which is slightly higher than the expected value (879) and frequency (15.57). CampC9 shows no significant for the observed (848) and the chi-square expected value (879) and chi-square frequency (27.78) higher than that of both campB7 and E15. The observed value (23) for Increaser III species found in camp E15 is very small than expect value (79.67) for X^2 and significantly lower value (1.53); while B7 observed value (105) which is slightly higher than the E15 observed value, differed from the

expected value (79.67) with a very low frequency of 7.93 though it is slightly higher than E15 chi-square frequency. For campC9 observed value (111) for Increaser III species, there is a slight difference between the expected value (79.67) of chi-square and with a frequency of (27.78) correspondingly. The observed value (186) for bare patches in camp E15 is slightly higher than the chi-square expected value 103.67 but not significantly different and (65.39) for the chi-square frequency. B7 observed value (75) for bare patches is lower than the expected value (103.67) and a low frequency of (7.93). C9 observed (50) for bare patches are significantly smaller than the expected value (103.67) and frequency of (27.78). Basal strike observed values E15 (73), B7 (84), and C9 (70) show no significant difference between camps and chi-square expected values (75.67) repeated for the three (3) camps, moreover, the chi-square frequencies for E15, B7, and C9 show no significant

4.2. Vegetation and richness of rangeland condition

Based on the results of the hierarchical cluster analysis, the dendrogram below gave the present/absent representation of species composition across the three experimental camps through plots numbers. Plots group under the same cluster number give an indication of species present within certain plots and show absence of other species as well within the dendrogram.

Cluster 1 is confined to four plots in campE15 (plot no. 2, 4, 10, &7) and each measured 10x15m^2 with a distance between plots at 20m. All plots maintained the following species composition below:*Schmidtia pappophoroides, Eragrostis nindensis*, *Heteropogon contortus*, *Eragrostis superba*, *Pogonathia squarosa, Melinis repens,* and *Aristida melidionalis.* The four plots above had diversity in some species that were not common to all. Plot three and four had fewer woody components while plot 1 and 2 were occupied with greater numbers of woody plants.

Cluster 2a this sub-cluster is composed of three plots (1, 3, & 9) of campE15 and has the characteristics of relatively good species richness composed of *S. pappophoroides, Anthephora pubescens*, *Eragrostis trichophora, Eragrostis enchinochloidea, Chloris virgata, Tragus beteronianus, Enneapogon cenchroides, Eragrostis rotifer, and Aristida melidionalis* were common species presence in all three plots. But plot 3 and 9 had three (3) species in common that did not surface in plot no.1.

Cluster 2b was mostly associated with Increaser II species and had at least five (5) different grasses that were not common to all. This cluster comprises of plot no. 5, 6, and 8 of E15 followed by plot no. 6 of campB7. All of these plots shared in common about 8 difference grass components. B7 is about 7km away from campE15 and had the highest density of woody vegetation.

Cluster 3 had about five (5) plots (1, 2, 3, 9 and 10) confined to campB7 and one (1) plot (no.8) northwest of the farm found in campC9. This was the largest cluster with about two herbaceous species not common to all of the experimental plots and seven (7) species present in all five (6) plots. CampC9 which is a dairy grazing ranch is about 10km away from campB7.

Cluster 4a was confined to camp B7 with three (3) experimental plots (4, 5, & 8) as well as a very low species richness and maintains six (6) common species namely, *Schmidtia pappophoroides, Anthephora pubescens, Fingerhurthia Africana* which are highly palatable grass species. They also occupied fewer increaser species like *E. trichophora, E. nindensis, E. cenchroides and C. virgata.*

Cluster 4b consisted of two (2) experimental plots from campB7 with plot no. 3 and 4. The plots had certain species in common which were not shared by the other plot. Plot 3 and 4 had the concentration of at least three (3) Decreaser species than the other experimental plots followed by thirteen (13) common grass species.

Cluster 5a was mostly associated with plots found in campC9 (plot no. 1, 2, 5, 9 and 10). These plots differed in the occupation of species like *Fingerhurthia Africana* present in plot 1, 5, and 10; *Pogonathia flekie* present in 1, 2, and 5.

But plot no.1 was the only plot in cluster 5a that was occupied by all grass species.

Cluster 5b which is a sub-cluster was confined to campC9 with at least two plots (6 and 7) and were occupied by common herbaceous species as follow: *Schmidtia pappophoroides*, *Cenchrus ciliaris*, *Eragrostis trichophora*, *Eragrostis nindensis*, *Pogonathia flekie*, *Chloris virgata*, *Enneapogon cenchroides*, *Pogonathia squarosa*, *Melinis repens*, *Aristida melidionalis*, *Eragrostis scopelophila*, and *Seteria verticilata*

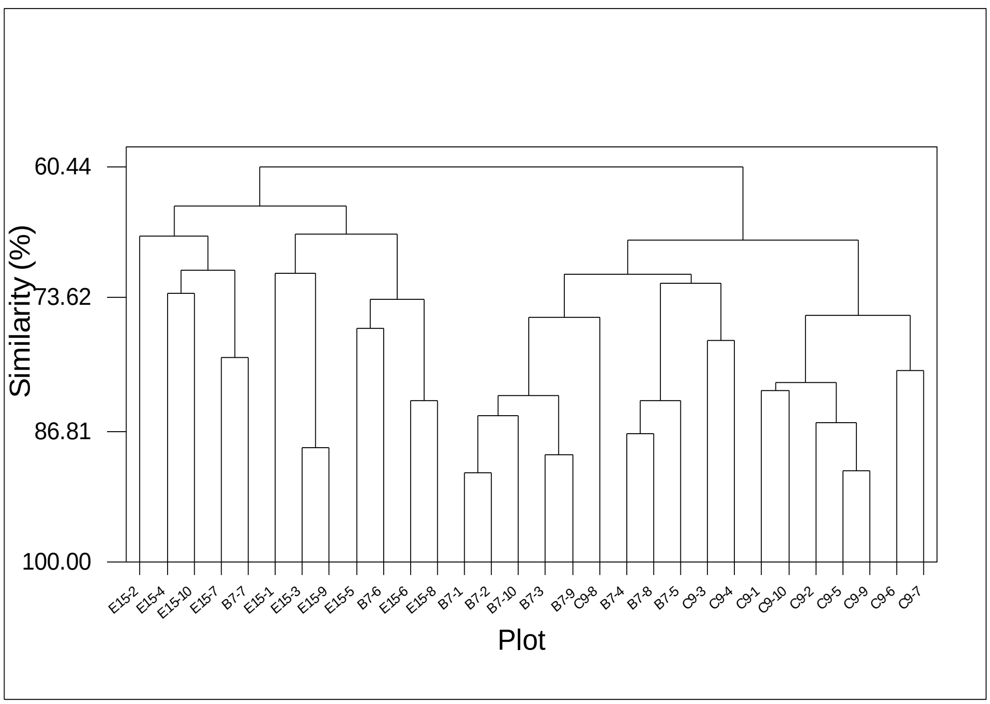


Figure 5: Hierarchical Cluster Analysis (HCA) dendrogram showing a classification of vegetation plots species richness into 7 main clusters based on

species presence and absence data at the Unam's Neudamm Experimental farm precisely in campB7, C9, and E15).

4.3. Vegetation and environmental relationships

Detrended correspondence Analysis (DCA) separates the three experimental camps (B7, C9, and E15) along axis 1and 2. These plots are shown by DCA in connection to HCA and are subdivided. Although there is a separation in the plots along DCA axis 1, there is an overlap in the two groups which shows a complex relationship between camps due to the level of degradation which varies in distances together in Group 2. It was evident in Figure 4 that most of the variation in the species data (18.3%) was explained along DCA axes 1; (28.3%), (35.4%), and (39.8%) of the variation were explained along DCA axes 2, 3 and 4 respectively. DCA axes 1, 2, 3 and 4, species fell along the gradients of 2.154, 1.641, 1.635 and 1.298.

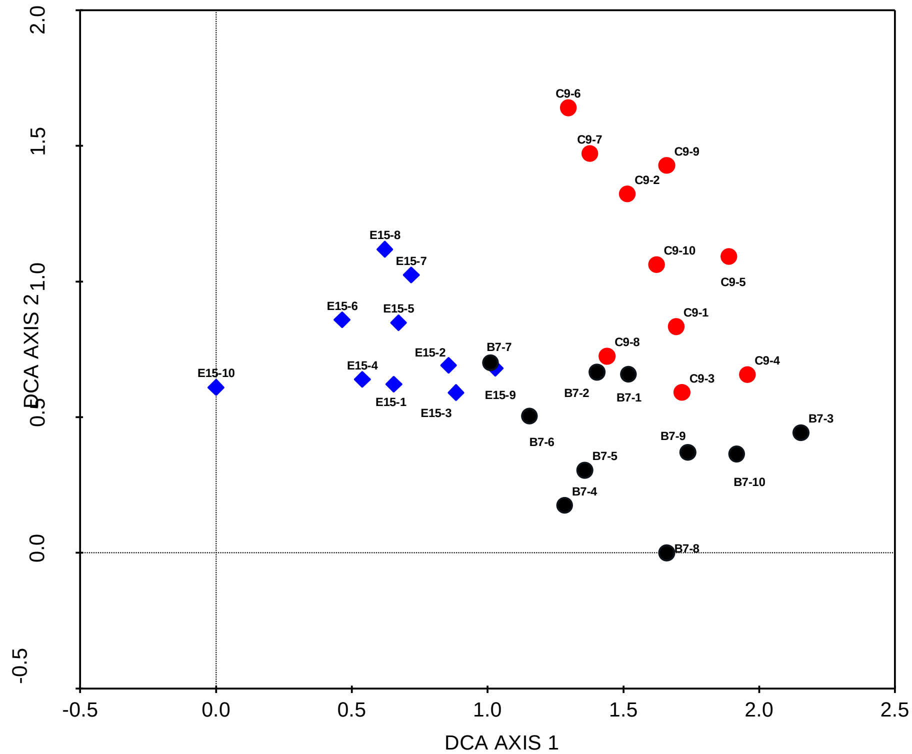


Figure 6: DCA ordination diagram showing separation of vegetation plots along the

DCA axis1. The black dots represent vegetation composition in campB7, red dots vegetation composition in campC9 and blue dot for campE15 as well.

The explanatory variables that significantly influenced species composition were Sodium ($P<0.001$, $F=2.72$, $df=2$), Sand ($P<0.05$; $F=1.76$), pH ($P<0.05$; $F=2.29$); Electrical conductivity ($P<0.05$; $F=1.70$); OM ($P<0.05$; $F=1.88$); clay ($P<0.05$; $F=1.92$).

The explainable variation in species composition along CCA axis 1 was positively correlated with sand, clay, and Mg, and negatively correlated to Na, and OM. The second axis was positively correlated to silt and negatively correlated to CEC, pH, Ca, and K.

CCA AXIS 1, CCA AXIS 2

E15, B7, and C9

The direction and influence of environmental variables indicate that P had positively influenced on species composition in direction of E15, plot 9, silt influence species in C9 plot, while Na and OM closeness to the distance of B7 plot 9 began stronger and had negative influence on species found in campB7. The distance from Mg to E15 plot 6 began stronger, clay and sand had positive interaction with species composition in campE15.

The variations in the species composition along the different axes were explained as follows: (20 .6%) of the variation was explained along CCA axis 1, (10.1 %) along CCA axis 2, (7 %) along CCA axis 3 and (12.04 %) along CCA axis 4. In total, (49.74%) of the observed variation in species composition was explained by the explanatory variables used in the CCA analysis

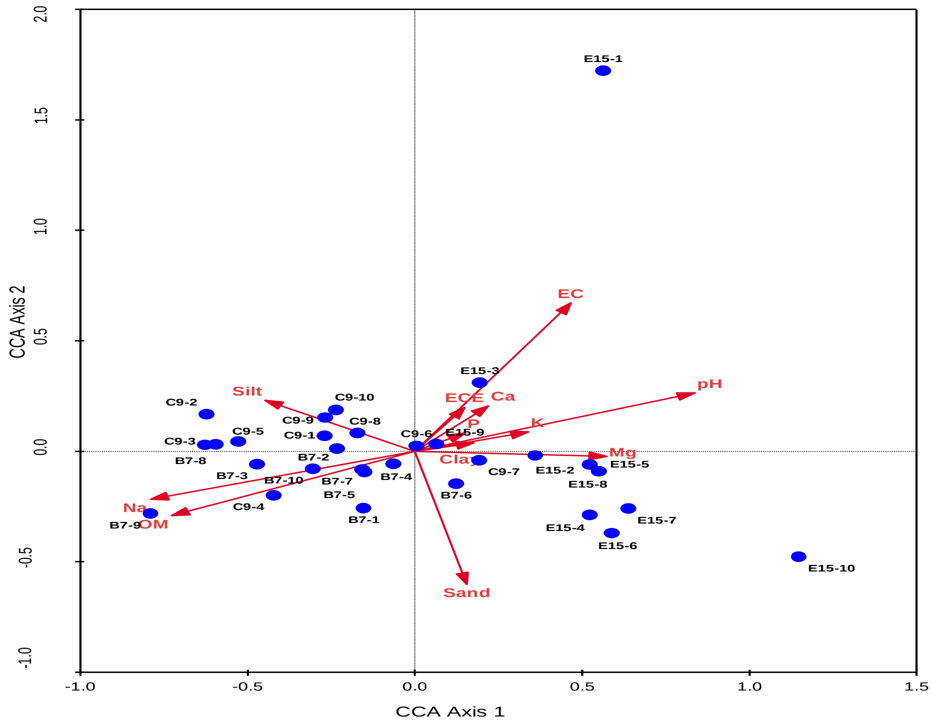


Figure7: Canonical correspondence analysis (CCA) ordination diagram indicating the influence of soil properties on vegetation composition at the Neudamm's Experimental farm, campE15, B7, and C9.

4.4. Woody plants density

Figure 6 show that there was highly a significant variation between the means of woody plants density (P<<0.001) between camps. The error bars at the top of the histogram represent the difference in mean of woody plants density with campE15 showing a lower level of woody plants density. But CampB7 and C9 are very similar in their mean density from the parallel position of the error bars showing no significant difference between both camps. These bars indicate the

Standard error of the means of all woody plants within the three contrasting camps by showing the level of significance different.

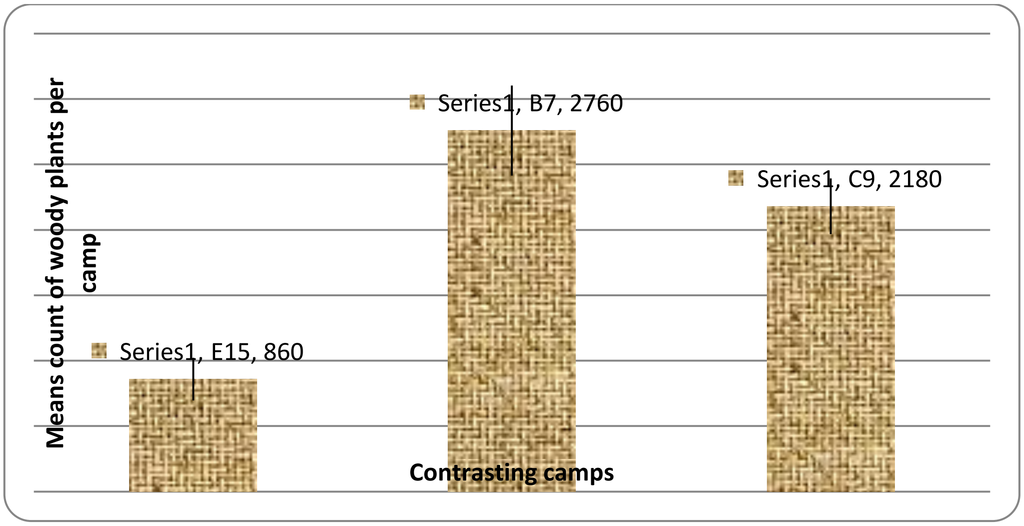


Figure 8: mean count of woody plants density per hectare between the three experimental camps; the error bars represent the means for each contrasting camp.

4.4.1. Distribution of woody plant density per ha

Table 2 shows the distribution of difference in mean of individual woody plants per hectare. The letters of the alphabet are used as superscripts showing the difference in significant among species. Species with the same superscript are not significantly different, and species which differ in letter(s) shows significant difference in their distribution across camps. Stars on the table reflect the total absence of certain species between whereas, zero values show how very small some species appeared across the three Camps with means and standard Error value being zero.

Species density	**E15**	**B7**	**C9**
Acacia mellifera	0.00	17.30 ± 3.50^{a}	9.10 ± 1.45^{b}
Acacia erioloba	×	×	0.00
Acacia hebeclada	4.20 ± 1.78^{a}	0.00	0.00
Acacia hereroensis	0.00	0.00	1.50 ± 0.50^{a}

Table 2: Shows the difference in means and SE of woody plants density per ha among the three contrasting camps at the Neudamm's experimental farm.

Continuity: **Table2**. Shows the difference in means and SE of woody plants density per ha among the three contrasting camps at the Neudamm's experimental farm

Species density	**E15**	**B7**	**C9**
Acacia karoo	1.80 ± 0.49^{a}	×	×
Blumea galpinii	0.00	0.00	0.00
Catophractus alexandrii	9.00 ± 8.01^{a}	×	5.20 ± 1.83^{b}
Eriocephalus luedretziannus	3.80 ± 1.07^{a}	$2.25a \pm 0.63^{a}$	3.00 ± 0.62^{a}
Leucosphoras benzii	4.50 ± 1.18^{a}	23.50 ± 5.93^{b}	14.83 ± 2.96^{b}
Lycium bosciifolium	×	0.00	×
Lycium eenii	0.00	0.92±0.92a	1.86 ± 0.34^{b}
Phaeoptilum spinosum	1.33 ± 0.67^{a}	×	0.00
Searsia ciliata	×	1.25 ± 0.25^{a}	$1.50a \pm 0.50^{a}$
Tarchonanthus camphorates	4.50 ± 3.5^{a}	0.50 ± 3.02^{a}	7.29 ± 2.06^{a}
Ziziphus mucronatas	×	0.00	2.50 ± 0.50^{a}

Total woody plant density was significantly lower in CampE15, slightly lower in C9 and higher in B7. Mean and SE with different superscripts within the rows differ significantly ($P<0.05$) and vice verse

4.4.2. Height class of woody density

Considering the utilization system of the three camps (figure 2), there is a significant association between tree height and tree density ($P=0.05$; Pearson $X^2=14.94$ m, df=4).The density of B7 maintains a significantly high tree count for all the tree height categories while E15 has significantly less tree counts overall. About sixty-five percent (65%) of the entire trees are <1m in height, and those between 1-2m accounts for about 25.5% and while >3 account for 9.5% respectively. There is a significant difference in percentage for tree count per camp, precisely E15 accounts for 13.5%, C9 37.8%, and B7 with about 48.7%. Some cells in the table of expected values were less than five (5) and therefore data was rearranged for analysis to proceed.

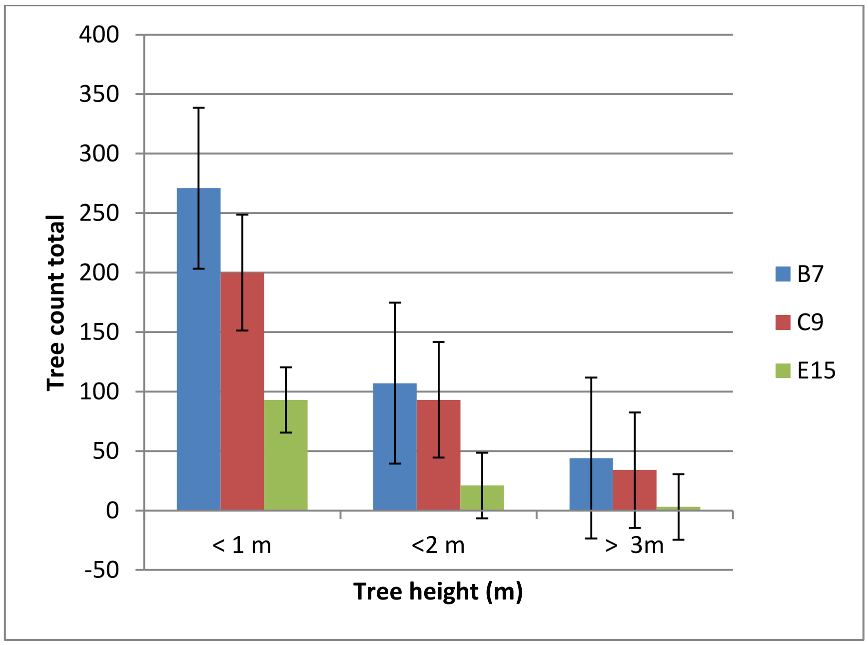


Figure9: Shows the correlation for total tree count and height class between the three experimental camps. The SE bars indicate the levels at which significant difference occurred between the three height classes and correlation to density of total tree count within camps.

4.5. Nutrient analysis of herbaceous compositions

There was a significant difference ($P<0.05$; df =2) between camps for %DM, %Moisture and %ash. Crude fiber % also showed a significant difference followed by neutral detergent fiber (NDF) ($P<0.001$). Ca was similar in E15 and B7 but differ in C7 significantly, P showed no difference between E15 and B7 but difference was shown between C7compared to the former and latter for P. Magnesium (Mg) test showed no difference in significance (P>0.05, df=2); K also differed significantly between camp B7, C9, and E15. Iron (Fe) and Zinc (Zn) showed no significant association (P>0.05) between the camps.

Table 3 shows the difference in means for herbaceous species chemical characteristics between the three (3) contrasting camps at the Neudamm experimental Farm.

Means of plant nutrients in the same row that are not sharing the same superscript are significantly different (P<0.05) in the test of equality for column means and vice verse. Crude protein which is an important nutrient for animals for animal feed analysis could not be done because the machine broke down.

Plants nutrient	**Camps**		
	E15	**B7**	**C9**

	Mean	Mean	Mean
% DM	92.65[a]	91.46[b]	93.46 [a]
% Moist	7.34 [a]	8.54 [b]	6.54 [a]
%Ash	7.27 [a]	6.84 [a]	10.46 [b]
CF	42.24 [a]	42.40 [a]	39.15 [b]
NDF	77.84 [a]	79.40 [a]	73.36 [b]
Ca	.233 [a]	.244 [a]	.320 [b]
P	.107 [a]	.106 [a]	.176 [b]
Mg	.089 [a]	.094 [a]	.103 [a]
K	.775[a,b]	.705 [a]	1.016 [b]
Fe	379.99 [a]	483.53 [a,b]	673.12 [b]
Zn	4.988 [a]	18.906 [b]	16.476 [b]

Table3: shows difference in mean of the chemical characteristics in herbaceous species between campE15, B7 and C9 at Neudamm Experimental Farm

4.6. Soil chemical analysis

There was no significant differenec ($P>0.05$, df=1) between the two layers of soil per plot in each one of the three (3) camps. But between the three camps, there were difference in significance ($P<0.05$, $P< 0.01$, $P< 0.001$, df=2) for soil chemical characteristics. In the studied areas of campE15, B7 and C9, the level of soil pH shown for E15 was greater than B7 and C9 indicating that the soil found in this camp is alkaline whereas CampB7 and C9 soils show pH level in the range of 6.25 meaning that the soils in these areas have similar property of acidity. Comparison of pH level for individual camp was analyzed by using a single factor analysis of variance. There was highly a significant difference ($p<0.001$, df=2) for pH level between the three contrasting Camps. Soil electrical conductivity (EC) was analyzed and it was concurred that there was no significant difference ($p<0.05$) between camps. There was extremely a difference in significance for soil organic matter (OM) between camps ($\alpha=0.001$, df=2)

Phosphorus level showed a highly significant ($\alpha=0.001$) difference between camps.

Potassium (K) showed a difference in significance ($p<0.05$, df =2) between the three camps. Calcium (Ca) data was log-transformed to achieve normality via the analysis using ANOVA. There was a variation between camps for Ca ($p<0.05$). Magnesium (Mg) shows significant between camps ($p<0.05$, df=2).

Table 4 shows the difference in means and SE for soil chemical characteristics between the three (3) contrasting camps at the Neudamm experimental Farm.

Means of soil nutrients in the same row that are not sharing the same superscript are significantly different ($P<0.05$, df= 2) in the test of equality for column means and vice verse.

Status of soil	E15	B7	C9
pH (H2O)	7.26±0.19[a]	6.23±0.07[b]	6.28±0.17[b]
EC-H2O US/cm	79.00±28.97 [a]	63.00±29.88 [a]	79.00±62.26 [a]
OM%	1.04±0.09 [a]	1.68 ±0.41 [b]	1.55±0.14 [b]
P ppm	0.41±0.09 [a]	0.2597±0.47 [a]	0.25±0.08 [a]
K ppm	98.00±48.16 [a]	95±14.64 [a]	70±9.70 [b]
Ca ppm	1273±317.90 [a]	614±60.17 [b]	735±197.38 [a] [b]
Mg ppm	254±51.56 [a]	113±12.56 [b]	109±20.26 [b]

Table 4: shows the difference in mean and SE error of the chemical characteristics of soil layers between E15, B7 and C9 at Neudamm experimental farm.

Continuity: Table1.3.

Status of soil	E15	B7	C9

Na ppm	0.00	15.25±2.34 [a]	2.5±1.12 [b]
Sand %	75.50±2.48 [a]	79.80±1.68 [a]	77.80±1.35 [a]
Silt%	14.80±1.84 [a]	11.50±1.41 [a]	14.00±1.57 [a]
Clay%	9.10±1.01 [a]	8.70±1.15 [a]	8.50±1.40 [a]

Relationship between camps for soil chemical compositions was significantly different. Means and SE error with different superscripts within the rows differ significantly ($P<0.05$, df=2) and vice versa.

Chapter 5

Discussion

5.1. Ecological condition and botanical diversity among the three management units

This study indicated that by assessing the veld condition of campE15, B7, and C9, using the ecological functional index results showed that utilization levels differed significantly among camps. E15 shows a significant level of Decreaser (28.13%) higher than the other management areas meaning that it is not over grazed and Decreaser species have a higher grazing quality which faces retrogression in a transitional of over-grazing, concurred by Foran*et al.* (1978). It is statistically proven that C9 level of Decreaser species (28.07%) was slightly lower than E15 (28.13%). However it did not differ but showed a significantly higher level of Decreaser species of higher grazing value. B7 shows a significantly lower level of Decreaser species (16.00%) which might probably derived from the high intensity of woody plants encroachment leading to the extinction of herbaceous layer. Productive capacity is reduced when preferred grasses like *Schmidtia pappophoroides, F. Africana, C. ciliaris, Anthephora pubescens and T. traindra*are replaced by desirable annual grasses and other *Eragrostis* species, and with species of *Aristida* (Tainton, 1999).

Increaser I in E15 (0.20%) differed significantly ($p<0.05$) among the other management units that showed (0.00%) for species occurrence. Increaser I species occur in veldt which is probably selectively utilized or underutilized. It was statistically proven among the three utilization levels that Increaser II species account for about (66.40%) in camp B7, followed by camp C9 with (56.53%) followed by camp E15 with about (52.87%). The high accumulation of these species occurs possibly in areas of veld under transitional state and increase at the result of light or heavy grazing. CampB7 was rested from grazing by livestock for the period of four (4) years though it had been utilized immensely by games which might probably be reason for the decline of species functional type of Increaser II occurrence. E15 and C9 did not differ in the percent of species distribution of Increaser II species. The results showed a significant difference level of utilization under different management (resting and utilization) conditions. Increaser II species escalates in veld under disturbed condition or overgrazed areas and is over taken by pioneer and sub-climax species such as *Aristida* species and portion of the *Eragrostis rigidior*. These species do well in areas of low rainfall and they produced much viable seeds which establishes on exposed soil. Increaser III showed a very highly significant difference for E15 (1.53) meaning that some parts of E15 probably experienced overgrazing; these grass species are unpalatable and dense climax grasses. They increased in a ranch condition that is detrimental to the extinction of palatable grass species and are direct indicators for the occurrence of Increaser III species. B7 and C9 did not differ in significant and are higher than E15.

CampE15 accounts for (12.40%) bare patches and (4.87%) basal strike. Bare patches are indicators for veld degradation probably derived from tramping form high grazing intensity by games or livestock. Basal may refer to stones, stumps of dead plants, and at the root of a tree. CampB7 had about (5.00%) for bare patches and (5.60%) basal strike while C9 had a significantly lower level of bare patches (3.33%) and (4.67%). The ecological condition percentages were obtained by multiplying the relative index value for each ecological functional group (Decreaser, Increaser I, Increaser II, and Increaser III) by their frequencies. The classes (poor, moderate, and good) were analyzed by using the condition scores of the three contrasting camps combined with the long term precipitation of the studied areas. The rainfall reports of Neudamm experimental were obtained from the meteorological office of Windhoek (2011), (2008-2010 rainfall patterns). In table 1.2, the veld condition index values together with the veld condition class were used to come out with the rangeland condition. According to Van Rooyen *et al*. (1996), for veld condition class determination, 0- 221.5 of the annual rainfall is considered as veld condition under a poor status comparing it with the range of the veld condition score, 221.5- 393.6 is a moderate veld health condition, and from 393.6-715.1 is a good veld condition. From the three managements unites, camp E15 is currently under grazing by small ruminants (goats and sheep) but show a good ranch condition form the result of the step method while C9 that is rested for one year period has the highest veldt condition .

5.1.2. CampE15

CampE15 carried a high veld condition score (559.19) next to C9, and it is in the range of good veld condition class (393.6-715.1). Looking at campC9 veldcondition score, it shows a very high good veld condition via the comparison to the annual rainfall patterns of Neudamm experimental farm.

CampE15 is the smallest (21hactare) among the three experimental camps and has 28.13% of Decreaser species which is the highest among the three camps. This result shows that campE15 has more palatable grass species like *Schmidtia pappophoroides* (66.11%), *Anthephora pubescens* (26.07%), *Fingerhurthia Africana* (1.90%), *Cenchrus ciliaris* (4.03%), and *Themeda traindra* (1.90%) and are found in a good veld which is well managed. It was statistically demonstrated by the Chi-square contingency table that campE15 carried a higher portion of Decreaser species.

Increaser I species (0.2%), *Cymbopogon* excavates which was assumed to be the only existence species usually found in veld condition which is selectively utilized or under-utilized.

For Increaser II species overall percentage in E15 was (52.87*%), Eragrostis trichophora* (9.21%), *Eragrostis nindensis (*12.68%), *Pogonathia flekie*

(14.12%), *Eragrostis enchinochloidea* (3.80%), *Chloris virgata* (7.10%), *Aristida congesta* (5.17%), *Heteropogon contortus (*3.40%), *Eragrostis superb* (10.84%), *Tragus beteronianus* (1.90%), *Enneapogon cenchroides* (93.53%) etc. Grasses in this ecological grouping are found poor veldt condition and increases as a result of light overgrazing. Increaser III species was about (1,53%) of the over percentage of Camp E15 which included *Cymbopogon plurinodis* (13,04%) *and Aristida melidionalis* (86.96%) and are grass species found in poor veld condition and increase as a result of heavy overgrazing (Van Rooyen *et al.* 1996).

Camp E15 had a greater level of bare patches which might have derived from excessive trampling resulting from heavy intensity of grazing and browsing pressures and have a detrimental long-term effects on the vegetation and soil, as is readily apparent in bush encroached rangelands (Owen-Smith, 1999). Bare ground was by far more common in E15 than campC9.

From the chi-square frequency (table 1.4), E15 carried the higher value (40.56) meaning that there was a maximum distribution of Decreaser species in E15 than the other camps.

.

5.1.3. CampB7

CampB7 condition score is slightly higher than the moderate score for the veld condition class, which assumes that B7 is gradually retrogressing and is not in a very good condition. CampB7 have spent four to five years without grazing and occupied about 48hactares of grassland. B7 carried about (16.00%) of the overall percentage of the three camps for Decreaser species. This percent was obtained from calculating the frequency of all Decreaser species and then divided by the total observed value of step-point (1500) and the dividend was as well multiplied by 100% to get the percent composition for each ecological functional type. Decreaser grass species (16.00%) is the second highest in this management unit. The high occurrenced of Decreaser species indicate veld in good condition. Grass species found in this group included *Schmidtia pappophoroides (*50.83%), *Fingerhurthia (*21.67%), *Cenchrus ciliaris Africana* (13.33%), *Anthephora pubescens* (14.17%).

Increaser I species was not encountered in B7, but rather Increaser II grasses which occupied about (66.40%) and served to be the highest between the three camps. For the total percentage of Increaser II species across campB7, *Eragrostis nindensis* carried about (29.32%), Increaser II which was the highest among the *Eragrostis species. E. scopelophila (*14.76%), *E. trichophora* (1.20%), *E. rotifer (*1.61%*), E. superba (*1.71%), *E. echinochloidea (*2.01%) *and E. lehmanniana carried about* (1.20%). *Aristida congesta* (5.62%), *Melinis repens* (21.18%)

which was the next higher ranking grass species in campB7 and it is a weak perennial tufted grass with attractive, hairy inflorescences. *Melinis repens* grows in disturbed places, in all soil types but especially in well drained soil. It is one of the most well known pioneer grasses in southern Africa and plays an important role in stabilizing disturbed soil. It is relatively palatable but has low leaf production. *Aristida stipitata* (2.21%), *Heteropogon contortus* (13.65%), *Chloris virgata* (0.02%) *Pogonathia flekii* (2.51%), *Pogonathia squarosa* (1.00%), and lastly followed by *Tragus beteronianus* (0.10%).

Increaser III grasses occupied about (7.00%) and they included *Aristida meridionalis* (65.71%) and *Microchloa caffra* which had about (34.29%). The null hypothesis which states that there is a similarity of species functional type distribution was rejected (α=0.05) in view of the very high chi-square frequencies (X^2=231.586, df =10, $p<0.001$).

It was statistically concurred from the Chi-square contingency table test that campB7 was significantly different in species distribution than the remaining camps.

B7 had the smallest value for bare patch among the three camps reference from the Chi-square contingency table (table 1.4) which assumes that during grazing period, some parts of the veld might have experienced tramping from grazing animals (livestock or game), or probably from rain erosion due to the topographical location of the veld. Over grazing is another factor which may have been responsible for the exposure of bare ground. CampB7 carried a very low percentage (Table 1) of basal strike than the other camps. Basal strike also may refer to stones, stumps, and other rooted plants etc.

5.1.4. CampC9

CampC9 was the second in ranking to E15 in terms of functional distribution of species and has a very high veld condition score grading it as the healthiest veld. C9 was second in Decreaser species with the overall average of (28.07%) which was slightly lower than E15. Decreaser species in C9 included *Schmidtia papppophoroides* with the average of (59.86%), *C. ciliaris (*21.38%), and *F. Africana* (18.76%). It is agreed by Foran *et al.* (1978) that Decreasers are grasses that dominate in good veldbut decrease under conditions of over-utilization. The chi-square frequency (table 1.5) shows that functional distribution of Decreaser species reflects a significant ($p<0.001$) lower level in C9 than campE15 and B7.

Increaser I species was found in E15 while in B7 and C9 it was infrequent. Increaser II species overall average was (56.53%) which was the second highest across the three experimental camps. These species included *Aristida congesta* (4.60%), *A. stipitata* (0.83%), *Aristida rhiniochloa had* (4.72%), *Chloris virgata* (2.12%), *Enneapogon cencholadea* (8.50%), *E. echinochloadea had about* (1.65%), *E. lehmanniana (1.65%), E. nindensis* (17.10%), *E. rotifer* (1.53%), *E. scopelophila* (12.85%), *E. trichophora* (5.42%), *H. contortus* (1.65%), *P. flekii*

*(*10.61%), *P. squarosa* (1.42%), *Seteria verticilata* (2.36%), *Stipagrostis uniplumis* (0.94%) *and Tragus beteronianus* (0.24%).

Amount these Increaser II species, *Melinis repens* was one of the most common grasses found on C9 which serves to be a strikingly attractive climax grass with its silvery-white or red panicles and is a widespread species found almost in all parts of Namibia's rangelands. This species is palatable and is found in union with others grasses like *Stipagrostis uniplumis and E. rigidior* in the central Kalahari region, where the three provide valuable grazing, but *M. repens* is most utilized than the other two.

Eragrostis. nindensis which had the second highest percent (17.10%) in campC9 is a valuable, palatable drought-tolerant climax grass and displays a preference for bare, exposed areas and stony or sandy soil, often with quartz inclusions. New leaves appear after a shower of rain and are bright green, but as they age, they assume a characteristic pale brown to reddish-brown color. These species were found in totally disturbed areas in campC9.

Increaser III was one of the small groups of species that occurred in C7 with the overall percentage of (7.40%). Grass species found in this ecological functional group include *Cymbopogon plurinodis* with (4.50%), *Microchloa caffra* (28.83%) and *Aristida meridionalis* (66.67%).

5.1.5. Functional distribution and composition of species

This study indicated that by assessing the veld condition of camps E15, B7, and C9, there was a significant difference in ecological functional type and utilization levels amount camps. Table 1.2 shows the actual counts of the ecological functional type of herbaceous species in the field and their occurrence across the three contrasting camps respectively while, table1.3 gives the relationship between the chi-square expected value in comparison to the observed value from the list of grass on a survey paper. It was statistically proven that there was a significant difference ($p<0.05$, df =10) between Decreaser compositions from the observe count to the chi-square expected value. There was a slight decrease in the chi-square expected value (361) for Decreaser species in E15; a relatively high value (361) in B7 and slightly lower value (361) in C9; while the observed value for E15 (422 >361); B7 (240<361), and C9 (421>361). The repetition in the chi-square expected values represent species composition across the three (3) contrasting camp, while the observed values show the level of significance ($P<0.05$) between camps. CampE15 had about (27.13%) of the overall Decreaser species composition and include: *Schmidtia pappophoroides* (66.11%), *Anthephora pubescens* 26.07%, *Fingerhurthia Africana* (1.90%), *Cenchrus ciliaris* (4.03%), and *Themeda traindra* (1.90%). CampC9 accounts for (28.07%) with Decreaser species like *Schmidtia papppophoroides* with the average of (59.86%), *C.* ciliaris (21.38%), *and F. Africana* (18.76%).

B7 had about (16.00%) of the overall species composition which include: *Schmidtia pappophoroides* (50.83%), *Fingerhurthia africana* (21.67%), *Cenchrus ciliaris* (13.33%), *Anthephora pubescens* (14.17%). For comparison of the overall percentage for Decreaser species in E15, B7, and C9; there was a significant difference ($P<0.05$) for species composition. The chi-square frequencies (table 1.4) for E15, B7, and C9 show all together a very significant difference for the distribution of species Decreaser species. The chi-square frequency for E15 (10.31) is significantly smaller than B7 with (40.56). CampC9 shows a significantly lower value for chi-square frequency than the former and latter. It is statistically shown that campB7 has a high distribution for Decreaser species than both E15 and C9 respectively.

The null hypothesis which states that there is no significant difference in the distribution of species functional type between camps was rejected ($\alpha=0.05$) in view of the very high chi-square calculated value ($X^2cal=255.14$; $df=10$; $P<0.001$).

Increaser I (table 1.2, column 3, row 2) shows an observed value significantly greater than the chi-square expected (1) and show no difference in the expected value thought there is a significant difference within the frequency for the three camps (table 1.4) meaning that camp E had higher proportion of distribution of increaser I species.

The observed value (793) for Increaser II in camp E15 is significantly lower ($p<0.05$) than the chi-square expected value (879) and followed by a very low frequency value (8.41) of chi-square while B7 differed in observed value (996) for Increaser II which is slightly higher than the expected value (879) and frequency (15.57). CampC9 shows no significant for the observed (848) and the chi-square expected value (879). E15 might have possibly obtained a moderate level of species composition for Increaser II while B7 had no difference in significant for species composition for the chi-square value and observed value respectively. C9 has greater proportion of Increaser II species precisely due to the high chi-square expected value. For species distribution, the chi-square frequencies assumed that C9 had a significantly lower distribution of Increaser II species; while B7 has significantly higher chi-square frequency (table 1.4. column 3, row 2) meaning that most of the grass species in Increaser II is widely distributed in campB7 possibly. E15 has an insufficient amount of Increaser II species distributed while C9 chi-square frequency shows a very small component of species distribution.

For campC9 observed value (111) for Increaser III species, there is a slight difference between the expected value (79.67) of chi-square and with a frequency of (27.78) correspondingly. The observed value (186) for bare patches in campE15 is slightly higher than the chi-square expected value (103.67) but not significantly different from the chi-square frequency (65.39). B7 observed value

(75) for bare patches is lower than the expected value (103.67) and a low frequency of (7.93). C9 observed (50) for bare patches are significantly smaller than the expected value (103.67) and frequency of (27.78). Basal strike observed values for E15 is (73), B7 (84), and C9 (70) show no significant difference between camps and chi-square expected values (75.67) repeated for the three (3) camps, moreover, the chi-square frequencies for E15, B7, and C9 show no significant.

5.2. Determination of vegetation structure, composition and ranch condition

Vegetative representations of the three experimental camps were not completely homogeneous in grass species association across the thirty (30) plots. Therefore, the Hierarchical Cluster Analysis (HCA) was used to show the presence/absence of species composition across camps. It also separated plots into sub-cluster with the species specification. Cluster 1and 2a were basically confined to camp E15 with plot number 2, 4, 7 and 10 representing Cluster 1 while plot number 1, 3 and 10 were represented by Cluster 2a. Cluster 1 maintained only one (1) Decreaser species and dominated by few Increaser II species while Cluster 2a was occupied by two (2) Decreaser species with one (1) Increaser I species follow by six (6) Increaser II species thought there were dissimilarity in the occurrence of quantity of these species. Cluster 2b was associated with plot number 5, 6 and 8 found in campE15 and plot number 6 of campB7. This cluster had high species diversity. Cluster 3 which was associated with plot number 1, 2, 3, 9 and follow by plot number 8 of campC9 had lower species diversity. Cluster 4a had very low species richness and maintains at least three (3) Decreaser species with fewer increaser species. For Sub-Cluster 4b, plots were concentrated in campB7 with thirteen (13) common grass species shared by the plots found in this cluster. Sub-Cluster 5a and 5b were basically associated to campC9 and both were diversified in species richness but Cluster 5b plots were similar in species occurrence while on the contrary, 5a which occupies plot number 1, 2, 5, 9 and 10 were very dissimilar in species distribution. The finding of the Hierarchical Cluster Analysis overall emphasized that there were similarity in species composition while species distribution varies across plots.

Detrended Correspondence Analysis (DCA) separated the three (3) camps along the DCA axis 1and 2 by showing both positions of overlap which reflects the complexity of the vegetative relationship. The magnitude of complexity shows the different levels of degradation of vegetative cover. It was streamlined in Figure 4 that diversity in species occurrence existed along DCA axes 1 at (18.3%)and reflecting axes 2, 3 and 4 at (28%), (35.4%) and (39.8%) respectively.

In the Canonical Correspondence Analysis (CCA), variables that influenced species communities were Sodium, Sand, pH, Electrical conductivity, Organic matter and Clay. The CCA indicates a positive influence of P directly to the species found in camp E15while silt had direct influence on species in camp C9, and Na, OM negatively influence B7.

There was also a positive correlation of species composition to environmental variable along axis 1 of the CCA with sand clay and Mg and reflects negatively correlations to Na and OM. From this finding the positive influenced of sand and clay might have derived from the soil parent materials while Mg which is found in the center atom of chlorophyll in green plants during the process of photosynthesis is not very important in soil due to the presence of Ca and P availability. The negative correlation of Na and OM might have derived from the cause of less vegetative cover of herbaceous plants (OM) and Na which is not an important nutrient in soil; its negative relation would have derived from the soil parent material present as well. CCA axis 2 was positively correlated to silt and negatively correlated to CEC, pH, Ca and K. Along the two axes, (20.6%) of the variation was explained along DCA axis 1and while the total of (49.74%) of the observed variation in species composition was explained by the explanatory variables.

5.3. Woody plants density

It is statistically proven that campB7 which is about 48 hectare was heavily occupied with woody plants with the means of 2760. This might have probably derived from lacked of thinning of younger tree; failure of applying chemical treatment to check woody plants multiplication over the years. CampC7 was significantly ($p<0.05$) higher in woody plants density as well than campE15 which had the lowest means. The abundance in woody plants is an indicator for retrogression of the grass component unavoidably reducing the productivity for savanna rangelands and it is detrimental to the herbivores that depend on the herbaceous layers for maintenance (Tainton, 1999). E15 with the lowest means of woody plants might have occurred probably from selective thinning of woody component and letting grazing continue within the said area. Similar research conducted by Walter (1971) concurred that due to the high density of woody layer, grasses under dense canopy find it difficult to survive because of insufficient sun ray that is detrimental to chlorophyll being captured and converted in to food. Among the *Acacia* species, *A. mllifera* was significantly ($p<<0.001$) high in density with the mean of (17.30±) in camp B7, (9.10±) in C9; Camp E15 was dominated by *A. herbeclada* (4.20±) which was significantly different from C9 and B7 with a very low amount. Amount the mean in density of woody plants, *Leucosphoras benzii* was highly significant between the three camps with B7 occupying larger mean (23.50±). There was a significant difference in the distribution of woody plants density across the three (3) experimental camps. *Catophractus alexandrii* differed in means for E15 (9.00±) and while C9 (5.20±) and B7 accounting for (0.00±). Other woody plants species found across the three camps are: *A. erioloba, A. erioloba, A. hereroensis, A.*

karoo, Blumea galpinii, Eriocephalus luedretziannus, Lycium bosciifolium, Lycium eenii, Phaeoptilum spinosum, Searsia ciliate, Tarchonanthus camphorates and Ziziphus mucronatas. The woody plants were been compared for difference of mean and SE test (table 2). Means and SE with the same superscript shows no significant difference and means and SE with different superscript shows a significant in their distribution.

5.3.1. Height class of woody density

Considering the three (3) utilization level in camp E15, B7 and C9, there was a significant association in the correlation of height class and woody density (α=0.05, df=4; Pearson X^2=14.94). Chi-square analysis for contingency tables was used to test for association between tree height and density as per camp size. Among the three height classes, woody plants <1m significantly differed between camps and had a high proportion per hectare than height class <2m and >3m. Woody layers <1m per hectare E15 (620tree/ha), B7 (1806.67tree/ha) and C9 (1333.33tree/hectare). Height class <1m was high in B7 probably due to browsing intensity by wildlife which leads to high vegetative growth of woody plants. Another reason would be due to the seasonal burning of veldt which is an indicator for new growth. CampE15 and C9 carried a very high density of tree per density. Woody plants <2m shows a greater ($p<0.05$) proportion

(713.33tree/ha) in campB7 than C9 (620tree/ha) and E15 (140tree/ha). Woody plants >3m across camps varies from (20tree/ha) campE15 to (293.33tree/ha) in B7 followed by C9 with (226.67tree/ha). This is possibly due to over stocking; through which palatable grasses are at the detriment of overgrazing and exposing the vegetation to invader species and bush encroachment, postulated by Solomon and Coppock (2002). Woody plants density per height class <1m in percentage was higher in campE15 (79.49%) significantly higher than B7 (64.22%) and C9 with (68%). In height class <2m, C9 dominates with the amount of (28.44%) followed by B7 with an estimate of (25.36%) and E15 with a smaller amount of (17.94%). Height class for wood plant >3 was by far lower in compared to the other height classes. Figure 3 gives a graphic representation for the various height classes and density of woody plants.

5.4. Nutrient analyses of herbaceous composition

It is found statistically that herbaceous composition differed significantly ($P<0.05$, df=2) in chemical characteristics between camps under different utilizations for percent dry matter, moisture and ash. From the mean of chemical interaction (table3) shows that campE15 and C9 had similar proportion of %DM than B7 and the former and latter have the higher output of DM which probably reflects a good veld condition for accommodating a manageable stocking rate of livestock or wildlife. Dry matter is the fraction of feed obtained from nonmoisture portion and or can be derived from diet which is heated in an oven for 24-48 hours. It has the essential organic component as well as ash (mineral) residues. In order word it is that portion of feed by which animal utilized for growth and maintenance by converting it into essential components (. Boyazoglu, 1997). Ash is an important portion (mineral) of animal feed used for better health and other reproductive activities. In rangeland condition it is healthy to get a ranch potent enough to stage a good intake of livestock or game which can depend on the veld for its productivity of maximum dry matter that these animals can convert in to functional substances for their survivor and maintenance. Crude fiber and neutral detergent fiber showed a significant variation ($p<0.05$) between the three (3) camps. CampE15 and B7 showed no difference in means but significantly differed with campC9.

Crude fiber percentage differed between camps ($p<0.05$) showing a higher means for E15 and B7 which probably derived from some functional type of plant species which is abundance in roughage; these camps are uniquely nutritional sources of animal maintenance possibly due to the presence of carbohydrate in CF% which is one of the most important elements in animal feed that can be referred to as the indigestible or slowly digesting components of feeds that occupies space in the gastrointestinal tract of animals (McDonald. 1995).

Chemically this component is a variable mixture of cellulose, hemicelluloses, some pectin and lignin, with indigestible proteins and lipids. Crude fiber contents being higher in campE15 and B7 could reflect a positive signal that both camp would do better for cattle during the summer when herbaceous layer is limited.

The NDF% of a feed is that portion referred to as the cell wall fraction which can be obtained by heating forage with neutral detergent in order to eliminate cell contents and the residues that remained is the cell wall. This cell wall is correlated to those indigestible fractions of the feed (cellulose, hemicelluloses and lignin). Most of the unpalatable grasses (Increaser II and III) are very high in this caption of feed and they were commonly high in camp C9 and B7 for Increaser II and III concurred by McDonalds*et al*(1988).

Calcium shows no difference in comparison between camps ($p>0.05$) meaning that the three camps possibly might have had Ca in its available form for plants intake. In rangeland science, Ca is an important element for growth and functional activities of the roots tips as well as a major element for animal feed. It is also found in good amount in the leaves of herbaceous and serves as a constituent for the plant cell wall. Total Ca availability of plants depends surely on the species Ca availability for example: cereal contains relatively a small quantity of Ca (0.5%) while other plants like legume requirement are high for Ca (1-2%). A research conducted by McDonalds (1987) indicated that Calcium (Ca) is the more abundant mineral element found in animal body. Dairy cow requires more Ca during pregnancy and lactation period. It is an important constituent and (98%) is utilized in the body for the formation of bones. The balance (2%) is distributed in extracellular fluids and soft tissues, and is involved in such vital functions as blood clotting, membrane permeability, muscle contraction, transmission of nerve impulses, cardiac regulation etc. Calcium deficiency symptoms appear initially as localized tissue necrosis leading to stunted plant growth, dead leaf margins on young leaves or curling of the leaves, and eventual death of terminal buds and root tips. Generally the new growth and rapidly growing tissues of the plant are affected first (Simon, 1978). For young growing animals, deficiency of Ca leads to poor bone formation known as rickets.

Phosphorus (P) was significantly different across camps probably due to the plants data collection during growing season (rainy season) which of course P turn to be marginal in plant for grazing animal from the field. It is important in plants for storage and transfer of energy obtained from photosynthesis and the metabolism of carbohydrates. Such energy is stored until required in the form of a compound known as adenosine triphosphate (ATP). P is required by pastures mostly during the rainy season than dried season and it served plants as well in its biochemical actions. Phosphorus plays an essential role in the conversion of energy from the pastures to energy that can be utilized by animal’s body. When a deficiency of phosphorus is present, the intake of the pasture is lowered and the feed conversion is poor, which in turn lowers the growth rate of the animal. With severe phosphorus deficiencies, the animals are extremely thin and have a stiff gate. Often their hooves grow out very long and curl inwards. During acute phosphorus deficiencies the bones start to de-mineralize.

Magnesium (Mg) did not differ between camps ($p>0.05$) and it is found at the central of chlorophyll molecule (center atom of chlorophyll). It is very important in the process of photosynthesis in plants tissue. Plants available Mg is about 15-(17%). Magnesium also is a necessary activator for many critical enzymes, including ribulosebiphosphate carboxylase (RuBisCO) and phosphoenolpyruvate carboxylase (PEP), both essential enzymes in carbon fixation. Thus low amounts of Mg lead to a decrease in photosynthetic and enzymatic activity within the plants. Deficiency of Mg first sign is the chlorosis (production of less chlorophyll by plant) of old leaves which progresses to the young leaves as the deficiency continues (Komwihangilo *et al*, 2001). Magnesium is correlated to Calcium and Phosphorus and (70%) of it is found in the skeleton, the remainder being distributed in the soft tissues and fluids. It was statistically proven that Potassium (K) differed significantly between camps. Potassium (K) is an essential nutrient for plant growth and large amounts are absorbed from the root zone in the production of most agronomic crops, or pasture lands and it is classified as a macronutrient responsible for biochemical reaction in plant. It as well being associated with movement of water, nutrients, and carbohydrates from one of the plant to another as well as the opening and the closing of the stomata during the period of photosynthesis. If K is deficient or not supplied in adequate amounts, growth of plant is stunted and yields are reduced. Iron (Fe) differed significantly between ($p<0.05$, df=2). Iron is very important in both animals and plants and it served as a cartilage for synthesizing the process of chlorophyll attraction from the atmosphere as well as been the central in animal's hemoglobin concurred by McLaren and Cameron (1997). Zinc (Zn) was significantly difference between camps which probably might have had lower amount in E15 due to the current grazing condition. While it was relatively high in B7 followed by C9 but did not show a difference in significance which might possibly derived for their various resting periods. Zn is an important element for plant enzymatic reaction for growth, starch production, seed maturation and production. It is an essential nutrient as well for animal. Animals acquire their bodily Zn from bran and germ of cereal grains. The by-product of animals such as meat meal and fish meal are usually richer sources of element than plant protein supplements.

5.5. Soil chemical analyses

Evidence provided statistically that soil analysis at the Neudamm experimental farm precisely camp E15, B7, and C9 differed significantly ($p<0.05$) in the top and subsoil layers in chemical characteristics. For soil pH between camps, E15 had a higher pH value (7) than C9 and B7 which had a pH between six-seven (6-7). The pH level is the most important soil factors measured in tend of acidity or alkalinity. Values for pH are based on a scale that ranges from 0 to 14. A pH of 7.0 is neutral. Values above pH 7.0 are alkaline and values below pH 7.0 are acidic. Most productive soils are acidic and generally range in pH from 4.0 to 7.0. The acidity of a soil increases ten-fold for each whole number decrease below pH 7.0. For example, a pH of 6.0 is 10 times more acidic than a pH of 7.0, a pH of 5.0 is 100 times more acidic than pH 7.0, and a pH of 4.0 is 1000 time s more acidic than pH 7.0. This means that a greater amount of lime is needed to increase the pH of a soil from 4.0 to 5.0 than from 5.0 to 6.0. Low soil pH can be a major contributing factor to plant's stand failure. Many forage seedlings are very susceptible to the adverse effects of acid soils like legume plant.

The level of pH above 7 hinders Phosphorus availability in soil for pasture uptake. The aim in managing soil pH is to adjust the acidity to the point where there is no toxic effect but rather speeding the availability of nutrients to its maximum. This condition is usually achieved when the soil pH is between 5.8 and 6.5.

There was no significant difference ($p>0.05$) in soil electrical conductivity (EC) between camps. Electrical conductivity (EC) is important to measure in soil in order to determine the relative amount of salt in the soil which may have adverse effect on plants growth at a maximum level.

Organic matter (OM %) shows a significant difference between camps ($p<0.05$). CampB7 was high in %OM than E15 and C9 probably due to the dense level of woody plants which accumulated a large portion of dead plants material under a moist condition for rapid decaying and then these materials are converted into soil essential minerals. Plant residues, on the surface help reduce the speed of wind and water runoff. Removal of plants material or burning of residues predisposes the soil to serious erosion. The resistant soil organic components, together with microorganisms (especially fungi) are involved in binding small soil particles into larger aggregates. Aggregation is important for good soil structure, aeration, water infiltration and resistance to erosion and crusting. CampE15 had the least mean for OM and it is possibly due to less plants material.

Phosphorus shows no significant difference between camps probably due to the small quantity available in soil. It has a residue effect on soil for three (3) to five (5) especially soil which has been top-dressed with P fertilizer. The total P present in most soil ranges from 0.02-0.15 depending on the soil parent material via it develops. It is obtained by plants in the form of a solution H_2PO_4 and HPO_4^{2-} ions. (H_2PO_4 : Di-hydrogen phosphate ion which is a conjugate base of Phosphoric Acid H_3PO_4 and the conjugate acid of mono-hydrogen phosphate ion HPO_4^{2-}) (McLaren and Cameron. 1997).

It is statistically proven that Potassium (K) differed significantly ($p<0.05$) between the three (3) experimental camps at Neudamm's Farm. E15 had a larger mean of K and followed by B7. Potassium is an essential nutrient for plant growth due to the large amounts absorbed from the root zone in the production of pastures or field crop. At times it is unavailable because it is held between layers of clay mineral which is referred to as fixed Potassium. In some pasture land K is supplied in a recommended amount for nutrition of plants, and information is provided on its reaction in soils, its function in forage plants and its role in crop production. Total K content in soil frequency ranges from (20,000ppm) twenty-thousand part per million. This quantity is not available for plants uptake because of the parent material and the effect of weathering of these material (Retrieved from the World Wide Web, November 16, 2011http://summitfertz.com.au/agronomypotassium.html).

There was a significant difference of Calcium (Ca) between camps with E15 accounting for a large amount in difference of means and SE, probably due to the reason for high production of palatable grass species and good veldt condition score. CampC9 was second in order of ranking with a very good sum of palatable grass species. Similar research conducted by McLaren and Cameron (1997) subjected that, Ca is the fifth most abundant element (3.64%) in mineral such as feldspar, Calcite ($CaCO_3$), dolomite ($CaCO_3.Mg\ CO_3$). Calcium is a macronutrient which influences the growth of both plants and animal.

Magnesium differed significantly ($p<0.05$) between camps which might probably derived from different soil physical properties (sandy, clay, silt and loam). Magnesium is the eighth most abundance element in the earth crust and account for 2% of the total mineral found in the earth crust. Plant requirement for Mg is less than Ca or K. Soil generally contains between 0.1 and 1% and all of this is not available to plants. The most obvious indicator of magnesium deficiency is the lost of green color between the veins, called interveinal chlorosis or yellowing.

Sodium was highly significant ($p<0.001$) between camps and account for relatively high amount in campB7. A research carried out by McLaren and Cameron (1997) proposed that Na is an essential nutrient for farm animals alone and not essential for crops. Their research report subjected that sodium is not important in the study of soil science.

There was no significant difference in percent sand for the three (3) camps respectively. This was proven statistically that the three contrasting camp had the same soil texture for sand. Percent silt and clay did not show any difference between camps. From the results of sand, silt, and clay, one can say that the soil texture at the experimental farm is proven to be homogeneous thought chemically; there were dissimilarities between camps for productivity

Chapter 6

Conclusion and recommendations

6.2. Conclusion

This study was conducted at the Neudamm no.63 farm in the Khomas Region, in order to assess the three camps precisely, E15 (21ha), B7 (48ha), and C9 (60ha) for plant functional types (Decreaser, Increaser I, Increaser II and Increaser III), woody plants density, height classes, as well as looking at nutrient components of both soil and plants to ascertain the health of these camps from the species diversities. A cross belt transect measured 1km in each camp was subdivided into (15X10 m^2) ten (10) plots for sample population. E15 currently under grazed by small farm ruminants showed a good veld condition score (599.19); nevertheless, C9 which was been grazed by diary and has been rested for two years indicated a good veld condition with the highest veldt condition score of (653.04) and lastly, B7 with a veld condition score projecting it as head from good to moderate (transitional state) veld. It was statistically proven that most of the palatable grass species (Decreaser species) were in high concentration in camp E15 and next followed by C7 thought both did not reflect a difference in significant. It is statistically proven that difference between campE15 and C7 for Decreaser species are insignificant in B7 which has been rested for the period of four (4) years differed from the other two camps.

It was proven that environmental relationship to species composition reflects the level of influence that occurred between species and its environment. Direct influence of environmental variable indicated that P had positive correlations on species composition in E15 while sand, clay, and Mg, had negative correlated with Na, and OM to their environment.

It was statistically concurred that there was highly a significant difference ($p<0.001$) in means for woody density per camps. B7 accounted for a very high aggregate of woody plant mean (2760), C9 (2180) and E15 (860). Woody plants per species density proves from the difference of means and SE that among the *Acacia* species, *A. mellifera* was the second most dominant species found in B7 (17.30 ± 3.50^{a}) followed by *Leucosphoras benzii (*23.50 ± 5.93^{b}) which was the most occurrence. CampC9 was second in turn of wood plants density per camp with the mean of *A. mellifera* (9.10 ± 1.45^{b}), *Tarchonanthus camphoratus* (7.29 ± 2.06^{a}), *Leucosphoras benzii* (14.83 ± 2.96^{b}). E15 carried a relatively low density of woody plants with its dominant species been *Catophractus alexandrii* (9.00 ± 8.01^{a}), *Leucosphoras benzii* (4.50 ± 1.18^{a}), and *Acacia hebeclada* (4.20 ± 1.78^{a}).

Considering the utilization systems of the three contrasting camps, camp E15 had high density of height class <1m which might further derived from application of seasonal fire to veld that leads to rejuvenation of younger tree.

Plants nutrients were analysis to determine nutrient variation between camps for dried matter, moisture, ash, CF, NDF, Ca, P, Mg, K, Fe, and Zn. Soil nutrients were analyzed for available P, K, Ca, Mg, Na, soil pH and EC. These elements were analyzed to determine the chemical properties of the soil and their ability to be taken up by plants in soluble form to meet up with ranch animal nutritional needs.

6.3. Recommendations

a) I recommend that selective thinning is enacted at the heavy encroached veldt either by chemical methods or by stocking such veld with browsers to help check woody plants encroachment especially ones in the range of browsers <1m.

b) Based on the current experience for the prolong resting period of veld condition for more than three-four (3-4) years without grazing, there must be a veld inspection trip at least twice a year for reseeding of conserved veld with Decreaser seed then at the end of the resting periods, most of the palatable grasses had reestablished at the optimum for livestock grazing. Veld under long resting period must be observed carefully the rejuvenation of woody vegetation by chemically treating at the early period of their existence.

3) There must be a rotation in seasonal stocking for grazers and browser during period of grazing to avoid depression on grass species and exposing browse plant as well for alternative periodically giving chance to grasses for recovery period.

4) Must was not done to ascertain information on the nutritional analyses of individually grass and browse due to lacked of laboratory sophistication; I therefore recommend that this expect be undertaken by another student to cover the uncovered.

References

Acocks, J. P. H. (1953). Veldt types of South Africa. Memoirs of the Botanical Survey of South Africa28: 1± 192.

Akpo, L.E. Banoin, M. & -Grouzis, M. (2003). Effet de l'arbre sur la production et la qualité fourragères de la végétation herbacée : bilan pastoral en milieu sahélien. *Revue deMédecine Vétérinaire 154*, 619-628.

Archer, S. (1995). Mechanisms of shrubland expansion:land use, climate or CO2 ? *Climatic Change* 29: 91± 99.

Association of Official Analycal Chemists, (1990). Official Methods of Analysis, GBC Scientific Equipment PTY Ltd., 1991. Flame Methods Manual for Atomic Absorption.

Association of Official Analytical Chemists International, (1995). Official methods of analysis of AOAC International, 16th edition, Method 4.6.01. (962.09), AOAC International, Maryland, USA.

Barnard, P. (Ed). (1998). Biological diversity in Namibia: A Country Study. Windhoek: Namibian National Biodiversity Task Force. ABC Press, Cape Town, South Africa.

Bayazoglu, P.A. (1997). Animal Nutrition. Concept and Application Published By J.P. van Schaik Publisher, 1064 Arcadia Street, Hatfirld, Pretoria.

Bayer, W. (1990). Use of native browse by Fulani cattle in central Nigeria. Agroforestry Systems 12, 217-228.

Briggs, J. Badri, M. & Mekki, A.M. (1999). Indigenous knowledge and vegetation use among Bedouins in the eastern desert of Egypt. Applied Geography 19, 87-103.

Briske, D.D., Heitschmidt, R.K. (1991). An ecological perspective. In: Heitschmidt, R.K., Stuth, J.W. Grazing management: an ecological perspective. Oregon: Timber Press, p.11-26.

Booysen, P De V, (1967). Grazing and grazing management terminology in southern Africa.

Bower, C.A. and Wilcox L.V. (1965). Soluble Salts, pages 933 to 951 in Methods of Soil Analysis, C.A. Black (ed.), Agronomy No. 9, American Society of Agronomy, Madison, WI.

Bouazoglu, P.A., (1997). Animal Nutrition, Concepts and Applications, (Revised edition). Published by J.L. van Schaik Publishers 1064 Arcadia Street, Hatfield, Pretoria

Conner, J.R. (1991). Social and economical influences on grazing management. In: Heitschmidt, R.K., Stuth, J.W. Grazing management: an ecological perspective. Oregon: Timber Press, p.259p.

Coppock, D. L. (1994). The Borana plateau of southern Ethiopia*: Synthesis of pastoral research, development and change, 1980-91*. ILCA (InternationallivestockCenter for Africa) Systems study 5. ILCA, Addis Ababa, Ethiopia. 299pp.

Danckwerts, JE, 1982a. Grazing capacity of sweetveld. 1. A technique to record grazing capacity.

De Klerk (1999). Bush Encroachment in Namibia. Report on Phase 1 of the Bush Encroachment Research, Monitoring and Management project. Ministry of Environment and Tourism, Directorate of Environmental Affairs. John Meinhert Printing.

De Klerk, J.N. (2004). *Bush encroachment in Namibia.* Report on Phase 1 of the Bush Encroachment Research, Monitoring and management Project, Ministry of environment and tourism, Windhoek, Namibia.

Dikman, J. (1998). Carrying capacity: outdated concept or useful livestock management tool?Overseas Development Institute, Pastoral Development Network. http://www.odi.org.uk/pdn/drought/dijkman.html

Directorate of Planning (1999). Agricultural statistics bulletin, September 1999. Ministry of Agriculture, Water & Rural Development, Windhoek.

Donaldson, C. H. (1967). Bush Encroachme nt with Special Re ference to the Blackthorn Problem of the Molopo Area. Te chnical Report, Department of Agriculture, Pre toria

Du Preez, C.C., Snyman, H.A., (1993). Organic matter content of a soil in a semi-arid climate with three long standing veld conditions. African Journal of Range and Forage Science 10, 108–110.

FAO. (2005). Agro-Ecological Zoning and GIS application in Asia with special emphasis on land degradation assessment in drylands (LADA). Proceedings of a Regional Workshop, Bangkok, Thailand10–14 November 2003. FAO, internet website: ftp://ftp.fao.org/agl/agll/docs/misc38e.pdf, accessed July 1, 2008.

FORAN, B.D., Tainton, N.M. and Booysen, P.D.V. (1978). The development of a method for assessing veld condition in the three grassveld types in Natal. Proc. Grassld. Soc. South Afr. 13: 27 -33.

Francina, C. P. and Smit, G. N. (2006). An evaluation of regrowth and coppicing of woody plants following mechanical bush thinning in marakele park, Thabazimi. 41st Annual Congress-Grassland Society of Southern Africa. 17th -21st July, 2006, Bela Bela, South Africa.

Glantz, M.H. (1976). Water and inappropriate technology: deep wells in the Sahel. Journal of International Law and Policy 6: 527± 540

Harrington, G.N. (1984), ‘Management of rangeland ecosystems’. In: G.N. Harrington, A.D. Wilson & M.D. Young (editors) Management of Australia’s Rangelands. CSIRO Publishing, East Melbourne, Australia. pp. 3-13.

Hardy, M. B. and Walker, L. S. (1991). Determining sample size for assessing species composition in grassland. *Journal of The Grassld Society of South Africa***8**: 70-73.

Hendershot, W.H., Lalande, H. and Duquette, M. (1993). Soil reaction and exchangeable acidity. Pages 141-145 in Soil Sampling and Methods of Analysis, M.R. Carter (editor). Canadian Society of Soil Science and Lewis Publisers.
Hermans C.; Vuylsteke F.; Coppens F.. "Systems Analysis of the responses to long-term magnesium deficiency and restoration in Arabidopsis thaliana". *New Phytologist***187**: pp. 132-144.

Komwihangilo, D.M. Sendalo, D.S.C., Lekule, F.P., Mtenga, L.A. & Temu, V.K., (2001). Farmer's knowledge in the utilization of indigenous browse species for feeding goats in semi arid central Tanzania. Livestock Research for Rural development 13,http://www.cipav.org.co/lrrd/lrrd13/6/komw136.htm

Kent, M. and Coker, P. (2003). Vegetation Description and Analysis. John Wiley &Sons Great Britain.

LADA (2005). Reflections on indicators for Land Degradation Assessment. The Land Degradation Assessment in Drylands Project (Unpublished).

Le Houerou, H.N. (1980). Chemical composition and nutritive value of browse in West Africa. In: Le Houerou, H.N. (Ed.), *Browse in Africa*. ILCA, Addis Ababa, pp. 261-289.

McDonald, P., Edward, R.A., Greenhalgh, J.F.D. and Morgan, C.A. (edit 5., 1995). Animal Nutrition, Addison Wesley Longman, Edinburgh Gate, Harlow, Essex CM20 2JE United Kingdom.

McDonald, P., Edwards, R.A. and Greenhalgh, J.F.D. (edit.4., 1988). Animal Nutrition. Longman Scientific and Technical, Longman Groups Ltd.

Longman House, Brunt Mills, Harlow Essex CM20 2JE, England , Associated Companies Throughout the world.

McLaren, R.G. and Cameron, K.C. (edit.1997). Soil Science. Sustainable Production and Environmental Protection. Published By OxfordUniversity Press. Great South Road, Greenlane, P.O. Box11-149, Auckland, New Zealand.

Mendelson, J. and Roberts, C. (1997). An Environmental profile and Atlas of Caprivi, Directorate of Environment and Tourism, Namibia.

Mendelsohn, J. (et al., 2002). Atlas of Namibia. David Phillips Publishers, Cape Town, South Africa.

Miller, W. P. and Miller, D. M. (1987). A micro-pipette method for soil mechanical analysis. Commun. Soil Sci. Plant Anal., 18: 1-15.

Mentis, M. T. (1981). Evaluation of the wheel-point and step-point methods of veldt condition assessment. *Proceedings of the Grassland Society South Africa 16*: 89-94.

Mtengeti, E.J. & Mhelela, A. (2006). Screening of potential indigenous browse species in semi-arid central Tanzania. A case of Gairo division. Livestock Research for Rural development 18, 9.

NDTF. (1997a). Towards a drought policy for Namibia. A discussion document prepared by the National Drought Task Force for a workshop at NeudammAgriculturalCollege 11-13 March 1997. National Drought Task Force, Windhoek.

Niamir, M. (1990). Traditional african range management techniques: implications for rangeland development. Community forestry: herders' decision-making in natural resources management in Arid and Semi-arid Africa. FAO, Rome.

O’Connor, T. G. (1985). A synthesis of field experiments concerning the grass layer in the savanna regions of southern Africa. *South African National Scientific Program Report* **114**: 1-125.

Okoli, I.C., Ebere, C.S., Uchegbu, M.C., Udah, C.A.& Ibeawuchi, I.I. (2003). A survey of the diversity of plants utilized for small ruminant feeding in south-eastern Nigeria. Agriculture, Ecosystems and Environment 96, 147-154.

Owen-Smith, N. and Danckwerts, J.E. (1997). Herbivory. In: R.M, Cowling, D.M., Richardson. And S.M. Pierce (eds). Vegetation of southern Africa, chpt.17. CambridgeUniversity, Cambridge, UK.

Owen-Smith, N. (1999). The animal factor in veld management. In: Tainton, N. M. (ed.) *Veld management in South Africa*. University of Natal Press

Pastor, J., Post, W.M., (1986). Influence of climate, soil moisture and succession on forest carbon nitrogen cycles. Biogeochemistry 2, 3–27.

Perrings, C. A. (1995). Biodiversity Loss: Ecological and Economic Issues. CambridgeUniversity Press, Cambridge.

Picardi, A. C., and Seifert, W. W. (1976). A tragedy of the commons in the Sahe Technology Review, May 1976: 42± 51.

Poluektov, N.S. (1973).Analytical Methods of Flame Photometry. ehnicka knjiga, Aelgrade.

(Retrieved from the World Wide Web, November 16, 2011http://summitfertz.com.au/agronomy_potassium.html).

Retrieved May 15,2011 from the World Wide Web, http://agr.gc.ca/pfra/land/fft1.htm 5/14/2007 10:35:28 AM (2 of 4)

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 and Forage Science***18**: 103-109.

Ringrose, S., Mathe son, W., Tempest, F., and Boyle, T. (1990). The development and causesof range degradation features in southeast Botswana using multitemporal Landsat MSS nimagery. Photogram metric Engineering and Remote Sensing 56: 1253± 1262.

Robertson, J.B. and Van Soest, P.U., (1981). The Analysis of Dietary Fiber in food. (Eds. W.P. T. James and O. Theander). Deller. New York.

Roothaert, R.L. & Franzel, S. (2001). Farmers' preferences and use of local fodder trees and shrubs in Kenya. Agroforestry Systems 52, 239-252.

Roques, K. G., O'Connor, T. G. and Watkinson, A. R. (2001). Dynamic of shrub encroachment in an African savanna: relative influences of fire, herbivory, rainfall and density dependence. *Journal of Applied Ecology* **38**: 268-280.

Roux, P. W., and Vorster M. (1983). Vegetation change in the Karoo. Proceedings of the Grassland Society of Southern Africa18: 25± 29.

Sanon, H.O. (1999). Livestock and world food security. MSc. thesis (Animal Science / Department of Animal Production Systems). Wageningen Agricultural University,Wageningen, 79 pp.

SAS®. (1996). User's guide: Statistics, Version 6.12. SAS Institute, Inc. Cary, NC, USA.

Schimet, D. S., Kittel, T. G. F., Knapp, A. K., Seastedt ,T. R., Parton ,W. J. and Brown V. B. (1991). Physiological interactions along resource gradients in tallgrass prairie. *Ecology* **72**: 672-684.

Seastedt, T. R., Briggs J. M. and Gibson D. J. (1991). Control of nitrogen limitation in tallgrass prairie. *Oecologia* 87: 72-79.

Scholes, R. J. and Walker, B. H. (1993). An African savanna: Synthesis of the Nylsuley study, Cambridge: CUP, pp. 51-126.

Shoenau, J.J. and Karamanos, R.E. (1993). Sodium Bicarbonate-Extractable P, K and N, pages 51-58 in Soil Sampling and Methods of Analysis, M.E. Carter Ed., Canadian Society of Soil Science, Lewis Publishers Soil Science Society of South Africa. 1990. Pages 24-1 to 24-3 in Handbook of Standard Soil Testing Methods for Advisory Purposes, SSSSA, Pretoria, RSA.

Simon, E.W. (1978): “The Symptoms of Calcium Deficiency in Plants.” New Phytologist 80 1-15.

Skarpe, C. (1986). Vegetation ecology in the western Kalahari in relation to large herbivore grazing, Unpublished Ph.D. thesis, Upsaliensis No. 33, UppsalaUniversity.

Skarpe, C., (1991). Spatial patterns and dynamics of woody vegetation in an arid savanna. Journal of Vegetation Science 2, 565–572.

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 of Range and Forage Science*.22 (1): 59-71.

Snel M, Bot A. (2003). Draft Paper: Suggested indicators for Land Degradation Assessment of Drylands. FAO, Rome.

Solomon, T.F.B. Desta., Coppock, D.L., (2002). Cattle population dynamics in the southern Ethiopia rangelands, 1980–97. Journal of Range Management 55, 439–451.

Solomon, T.B. et al, (2007b). 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

Solomon, T.B.(2003). Rangeland evaluation and perceptions of the pastoralists in the Borana zone of southern Ethiopia. Ph.D. Thesis, University of the Free State, Bloemfontein, South Africa.

Soil available Potassium:Http://summitfertz.com.au/agronomy_potassium.html

Sweet, R.J. (1998a). A rainfall model for estimating carrying capacity. Northern Regions Livestock Development Project (NOLIDEP), Windhoek.

Snyman, H.A., (1998). Dynamics and sustainable utilization of rangeland ecosystems in arid and semi-arid climates of South Africa. Journal of Arid Environments 39, 645–666.

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

Snyman, H.A. (2002). Fire and the dynamics of a semi-arid grassland: influence of soil characteristics. *African Journal of Range and Forage Science*. 19: 137-145.

Tainton, (N.M., 1982). Veldt evaluation and Sweet veldt observation. Proceeding of Beef and Game on Sweet veldt Symposium, October 1982. Hlabisa Soil conservation Committee, pp. 24–30.

Tainton, N. M. (1999). *Veld management in Southern Africa*. University of Natal Press Pietermaritzburg.

Thapa, B., Walker, D.H. & Sinclair, F.L. (1997). Indigenous knowledge of the feeding value of tree fodder. Animal Feed Science and Technology 68, 37-54.

Tidmarsh, CEM, 1951. Veld management studies at the Grootfontein College. 1934– 1950. Pature Research in South Africa.

Trollope, W. S. W., Trollope, L. A. and Bosch, O. J. H. (1990). Veld and pasture management terminology in southern Africa. Journal of The Grassland Society of South Africa7: 52-61.

Thorne, P.J. Subba, D.B., Walker, D.H., Thapa, B., Wood, C.D. & Sinclair, F.L. (1999). The basis of indigenous knowledge of tree fodder quality and its implication for improving the use of tree fodder in developing countries. Animal Feed Science and Technology 81, 119-131.

UNEP. (2008). Africa: Atlas of Our Changing Environment. Division of Early Warning and Assessment (DEWA) United Nations Environment Programme (UNEP). Nairobi00100, Kenya.Van Rooyen, N., Bezuidenhout, D., Theron, C.K.

VAN HOVEN, W. 2002. Nutrition. pp. 243-276. *In:* Bothma, J. du P. (Ed.). *Game ranch management.* Van Schaik Publishers: Pretoria.

VAN OUDTSHOORN, F. 2004. *Guide to grasses of Southern Africa.* Second edition. Briza Publications: Pretoria.

VAN ROOYEN, N., Bredenkamp, G.J. and Theron, G.K. (1996). Veld management. Pp. 539 – 572. In*:*Bothma, J. du P. (Ed.).*Game ranch management.* Fourth edition. Van Schaik Publishers: Pretoria.

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

Walkley, A. and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37:29-38.

Walter, H. (1971). Ecology of tropical and Subtropical Vegetation. Oliver and Boyd, Edinbu.

Wilson, A.D., Tongway, D.J., Graetz, R.D. and Young, M.D. (1984). Range inventory and monitoring. In: Harrington, G.N., Wilson, A.D. and Young, M.D. (Eds.). Management of Australia's rangelands. CSIRO, Melbouurne.

Appendices

Appendix1. Ecological functional type of herbaceous

Camp-E15 veld condition

Species type	**Basal strike**	**Nearest plant**	**Total**	**Freque ncy**	**Relative Index value**	**Product/ Condition index**
Decreaser	73				10	
		Schmidtia pappophoroides	257	20.5		
		Anthephora pubescens	132	10.9		
		Finferhurthia Africana	8	0.6		
		Cenchrus ciliaris	17	1.3		
		Themeda traindra	8	0.6		339
		TOTAL	422			

Continuity: campE15 veld condition

Species type	**Basal strike**	**Nearest plant**	**Total**	**Frequency**	**Relative Index value**	**Product/ Condition index**
Increaser I					7	
		Cymbopogon excavatus	3	0.2		1.4
			3			
Increaser II					4	
		Eragrostis trichophora	73	5.5		
		Eragrostis nindensis	102	7.8		
		Pogonathia flekie	112	8.5		
		Eragrostis enchinochloidea	30	2.2		
		Chloris virgata	56	4.2		
		Aristida congesta	51	3.9		
		Heteropogon contortus	28	2.1		
		Eragrostis superb	116	9		

Continuity: campE15 veld condition

Species type	**Basal strike**	**Nearest plant**	**Total**	**Frequency**	**Relative Index value**	Product/ Condition index
Increaser II					**4**	
		Tragus beteronianus	15	1.1		
		Enneapogon cenchroides	25	1.9		
		Eragrostis rogidior	1	0.1		
		Eragrostis rotifer	37	2.8		
		Pogonathia squarosa	30	2.2		
		Melinis repens sub sp. Grandiflora	6	0.5		
		Melinis repens	54	4.1		

Continuity: campE15 veld condition

Species type	Basal strike	Nearest plant	Total	Frequency	Relative Index value	Product/ Condition index
Increaser II					**4**	
		Eragrostis lehmanniana	36	5.3		
		Stipagrostis uniplumis	13	1		
		Aristida stibitata	8	0.6		251.2
Increaser III			**793**			
					1	
		Cymbopogon plurinodis	3	0.2		
		Aristida melidionalis	20	2.1		2.3
			23			
Total			1,241	100%		599.19

Appendix2. Ecological functional type of herbaceous

Camp B-7 veld condition

Species type	**Basal strike**	**Nearest plant**	**total**	**Frequency**	**Relative index value**	**Product/ Condition index**
Decreaser	84				10	
		Schmidtia pappophoroidis	122	8.9		
		Fingerhurthia africana	52	3.8		
		Cenchrus ciliaris	32	2.3		
		Anthephora puberscens	34	2.7		177
			240			
Increaser II					4	
		Eragrostis nindensis	293	21.4		
		Aristida congesta	57	4.1		
		Melinis repens	212	15.5		
		aristida stibitata	17	1.2		

Continuity: campB7 veld condition

Species type	**Basal strike**	**Nearest plant**	**total**	**Frequency**	**Relative index value**	**Product/ Condition index**
Increaaser II					4	
		aristida stibitata	17	1.2		
		Eragrostis trichophora	19	1.3		
		Chloris virgata	5	0.3		
		Eragrostis scopelophila	143	11.2		
		Tragus beteronianus	1	0.07		
		Pogonathia flekii	20	1.8		
		Heteropogon contortus	136	9.9		
		Stipagrostis uniplumis	14	1		
		Eragrostis rotifer	17	1.2		
		Eragrostis superba	17	1.2		

Continuity: campB7 veld condition

Species type	**Basal strike**	**Nearest plant**	**total**	**Frequency**	**Relative index value**	**Product/ Condition index**
Increaaser II					4	
		Eragrostis echinochloidea	20	1.4		
		Pogonathia squarosa	11	0.8		
		Eragrostis lehmanniana	14	1		294
			996			
Increaser III					1	
		Aristida melidionalis	60	4.9		
		Microchloa caffra	45	3.2		8
			105			
Total			1341	100%		483.89

Appendex3. Ecological functional type for herbaceous

Camp C-9 veld condition

Species type	**Basal strike**	**Nearest plant**	**total**	**Frequency**	**Relative index value**	**Product/ Condition index**
Increaser	70				10	
		Schmidtia pappophoroidis	252	15.4	154	
		Cenchrus ciliaris	90	7	70	
		Fingerhurthia africana	79	3.7	37	261
Increaser II			421		4	
		Melinis repens subsp repens	185	13.4	53.6	
		Eragrostis nindensis	145	10.5	42	
		Pogonathia flekii	90	7	28	
		Eragrostis trichophora	46	3.3	13.2	
		Aristida congesta	39	3	12	
		Enneapogon cenchloadea	72	5.2	20.8	
		Heteropogon contortus	14	1	4	

Continuity: CampC9 veld condition

Species type	**Basal strike**	**Nearest plant**	**total**	**Frequency**	**Relative index value**	**Product/ Condition index**
Increaser II					4	
		Eragrostis scopelophila	109	7.9	31.6	
		Eragrostis echinochloadea	14	1	4	
		Aristida rhiniochloa	40	2.9	11.6	
		Tragus beteronianus	2	0.1	0.4	
		Chloris virgata	18	1.3	5.2	
		Aristida stibitata	7	0.5	2	
		Eragrostis lehmanniana	14	1	4	
		Pogonathia squarosa	12	0.9	3.6	
		Stipagrostis uniplumis	8	0.6	2.4	
		Seteria verticilata	20	2.1	8.4	
		Eragrostis rotifer	13	1		246.8

Continuity: CampC9 veld condition

Species type	**Basal strike**	**Nearest plant**	**total**	**Frequency**	**Relative index value**	**Product/ Condition index**
Increaser III			848		1	
		Cymbopogon plurinodis	5	0.4	0.4	
		Microchloa caffra	32	2.3	2.3	
		Aristida melidionalis	74	10	10	12.7
			111			
Total			1380	100%		653.04

Appendix4.One-way ANOVA for woody plant density

	E	*B*	*C*
Mean	860	2760	2180
Standard Error	163.4353423	343.863309	212.4635045
Standard Deviation	516.8279318	1087.39126	671.8685939

Appendix5. Total count for height class and percentage per camp

Density	**Tree count (total)**	**Percentage Tree Count**
E15 (21)	117	13.5
B7 (48)	422	48.7
C9 (60)	327	37.8
TOTAL	866	100.0

Appendix6. One-way SPss test for significant for soil chemical characteristics between camps.

ANOVA

Soil nutrient	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
pH (H2O) Between Group within groups Total	13.480 13.286 26.766	2 57 59	6.740 0.233	28.916	0.000
EC (H2O)us/CM Between Within Groups Total	3172.633 951447.10 954619.733	2 57 59	1586.054 16692.054	0.095	0.909
OM% Between Groups Within Groups Total	4.476 14.353 18.829	2 57 59	2.238 0.252	8.887	0.000

Continuity: significant for soil chemical characteristics between camps.

ANOVA

Soil nutrients	**Sum of Squares**	**df**	**Mean square**	**F**	**Sig.**
Pppm Between Groups Within Groups Total	5.656 55.199 60	2 57 59	2.828 0.968	2.920	0.062
Kppm Between Group Within Groups Total	9409.633 87909.350 97318.983	2 57 59	4704.817 1542.269	3.051	0.055
Ca ppm Between Groups Within Group Total	4934623.633 30579829.300 35514452.933	2 57 59	2467311.817 9912.992	13.602	0.00
Mg ppm Between Group Within Groups Total	269680.433 565040.550 834720.983	2 57 59	134840.217 9912.992	13.602	0.000
Na ppm Between Groups Within Group Total	1751.700 14149.950 15901.650	2 57 59	875.850 248.245	3.528	0.036

Appendix7. One-way SPss test for plant nutrient analysis

ANOVA

Plant nutrient	**Sum of square**	**df**	**Mean Square**	**F**	**Sig.**
%DM Between Groups Within Groups Total	40.607 71.318 111.924	2 57 59	20.303 1.251	16.227	0.000
%OM Between Groups, within Groups Total	40.651 71.083 111.733	2 57 59	1.247	16.299	0.00
%Ash Between Groups Within Groups Total	156.314 149.124 305.438	2 57 59	78.157 2.616	29.874	0.000
CF Between Groups Within Groups Total	134.482 389.992 524.474	2 57 59	67.241 6.842	9.828	0.000
NDF Between Groups Within Groups Total	392.645 544.249 936.895	2 57 59	196.323 9.548	20.561	0.000
Ca Between Groups Within Groups Total	0.090 0.490 0.580	2 57 59	0.045 0.009	5.218	0.008

Continuity: One-way SPss test for plant nutrient analysis

ANOVA

Plant nutrient	**Sum of square**	**df**	**Mean Square**	**F**	**Sig.**
P Between Groups Within Groups Total	0.064 0.112 0.176	2 57 59	0.32 0.002	16.201	0.000
Mg Between Groups Within Groups Total	0.002 0.054 0.056	2 57 59	0.001 0.001	1.044	0.356
K Between Groups Within Groups Total	1.066 7.075 8.142	2 57 59	0.533 0.124	4.295	0.018
Fe Between Groups Within Groups Total	883940.288 5095072.714 5979013.002	2 57 59	441970.144 89387.241	4.944	0.010
Zn Between Groups Within Groups Total	2210.599 7350.240 9560.838	2 57 59	1105.299 128.952	8.571	0.001